Government of Nepal

Ministry of Physical Infrastructure and Transport

Federal Capital City Public Transport Authority

Babarmahal, Kathmandu

Analytical Public Route Hierarchy for Optimizing Urban Public Transportation Networks using Multicriteria Approach

(FCCPTA/CS/081/82-007)

FINAL REPORT

AUGUST, 2025

Submitted By:

SHAH ENGINEERING CONSULTANT PVT. LTD.

KOTESHWOR, KATHMANDU

Email: shahengineeringconsultant2076@gmail.com

ACKNOWLEDGEMENT

The consultant team would like to take this opportunity to convey sincere thanks and gratitude to executive officer and staffs of the Federal Capital City Public Transport Authority (FCCPTA) who have helped for overall planning, organizing meetings and so on, from the very beginning to the completion of the report. Again, the team would like to acknowledge the technical team of the FCCPTA including engineers and planner regarding their technical inputs about route details, and other information. The consultant team would also like to express sincere thanks to all the concerned officials of the FCCPTA who have helped directly or indirectly and contributed at every step up to this phase towards the completion of this project.

Furthermore, the team would like expresses sincere gratitude to the officials Of Department of Roads (DoR) and Department of Transport Management (DoTM) for providing the data regarding Route Registration and operation details. The team expresses sincere gratitude to the Public Transportation operators and staffs, Passengers as well as Traffic Police for their patience and co-ordination during the onboard surveys. Finally, the team would like to acknowledge all the helping hands that were directly or indirectly involved in preparation of this Report

Shah Engineering Consultant Pvt. Ltd.

Koteshwor, Kathmandu

ACRONYMS/ABBREVIATIONS

AHP	Analytic Hierarchy Process
BA	Boarding Alighting
BRT	Bus Rapid Transit
CI	Connectivity Index
DoTM	Department of Transport Management
GIS	Geographic Information System
GPS	Global Positioning System
MCDM	Multicriteria Decision-Making
OD	Origin and Destination
ToR	Terms of Reference
PT	Public Transport
Min.	Minute
KV	Kathmandu Valley
Km.	Kilometre
Sq. km	Square Kilometre
VLR	Vehicle Load Ratio
DCR	Demand-Capacity Ratio

TABLE OF CONTENTS

ACRONYMS/ABBREVIATIONS II

TABLE OF CONTENTS III

LIST OF TABLES IV

LIST OF FIGURES V

INTRODUCTION 1

METHODOLOGY 8

DATA ANALYSIS AND FINDINGS 35

CONCLUSION 68

REFERENCES 70

ANNEX-I: DATASHEETS 71

ANNEX-II: GIS MAPS 76

LIST OF TABLES

Table 1: List of Selected Public Transportation Routes 9
Table 2: Coding Convention for Direction and Trip 16
Table 3: List of Tier-A Public Transportation Routes 18
Table 4: List of Tier-B Public Transportation Routes 20
Table 5: List of Tier-C Public Transportation Routes 21
Table 6: List of Tier-D Public Transportation Routes 22
Table 7: Attributes of Tier-A Public Transportation Routes 45
Table 8: Attributes of Tier-B Public Transportation Routes 48
Table 9: Attributes of Tier-C Public Transportation Routes 51
Table 10: Attributes of Tier-C Public Transportation Routes 53
Table 11: Saaty Scale and Triangular Fuzzy Number 57
Table 12: Weighted Parameters 57
Table 13: Fuzzy Pairwise Matrix 60
Table 14: Final Weights of Selected Parameters 61
Table 15: Hierarchy of Tier A Routes 62
Table 16: Hierarchy of Tier B Routes 63
Table 17: Hierarchy of Tier C Routes 64
Table 18: Hierarchy of Tier D Routes 65

LIST OF FIGURES

Figure 1:Spatial Distribution of Selected Bus Routes in Kathmandu Valley 10
Figure 2: Sample Datasheet of Boarding Alighting Survey 12
Figure 3: Tier-A Public Transportation Routes Map 19
Figure 4: Tier-B Public Transportation Routes Map 20
Figure 5: Tier-C Public Transportation Routes Map 21
Figure 6: Tier-D Public Transportation Routes Map 23
Figure 7: Line-Chart showing the Variation of Route length across selected routes 35
Figure 8: Line-Chart showing the Variation of Station Number across selected routes 36
Figure 9: Average Ridership Heatmap (Towards CBD) 37
Figure 10: Average Ridership Heatmap (Away from CBD) 37
Figure 11: Average Vehicle Load Ratio Heatmap (Towards CBD) 38
Figure 12: Average Vehicle Load Ratio Heatmap (Away from CBD) 39
Figure 13: Average Demand Capacity Ratio Heatmap (Towards CBD) 40
Figure 14: Average Demand Capacity Ratio Heatmap (Away from CBD) 40
Figure 15: Spatial Distribution of Stops along the selected routes 41
Figure 16: Spatial Distribution of Critical sections along the selected routes 42
Figure 17: Line-Chart showing the Variation of Travel time across the selected routes 43
Figure 18: Bar Chart showing the Average Demand and Travel Time of Tier-A PT Routes 46
Figure 19: Chart showing the distribution of Maximum pax & seat capacity of Tier-A Routes 46
Figure 20: Heatmaps of VLR and DCR of Tier-A PT Routes 47
Figure 21: Bar-Chart showing the Average Demand of Tier-B PT Routes 49
Figure 22: Chart showing distribution of Max pax vs seat Capacity & travel times of Tier-B Routes 49
Figure 23: Heatmaps of VLR and DCR of Tier-B PT Routes 50
Figure 24: Bar-Chart showing the Average Demand of Tier-C PT Routes 52
Figure 25: Chart showing distribution of Max pax vs seat Capacity & travel times of Tier-B Routes 52
Figure 26: Heatmaps of VLR and DCR of Tier-C PT Routes 53
Figure 27: Bar-Chart showing the Average Demand of Tier-D PT Routes 55
Figure 28: Chart showing distribution of Max pax vs seat Capacity & travel times of Tier-B Routes 55
Figure 29: Heatmaps of VLR and DCR of Tier-B PT Routes 56

Chapter 1
INTRODUCTION

1.1 Background

Urban public transportation is a cornerstone of sustainable city development, especially in rapidly urbanizing regions like the Kathmandu Valley. Efficient and reliable transport networks ensure equitable mobility, reduce traffic congestion, lower environmental pollution, and support economic productivity. In Kathmandu, however, the existing public transport network is largely unstructured, with overlapping routes, inconsistent service frequency, limited coverage, and inefficient allocation of resources.

Most routes have historically evolved in an organic and uncoordinated manner, driven more by operator convenience than by passenger needs or system-level planning. This has led to poor modal integration, underutilized routes in some areas, and excessive congestion in others. In the absence of a formal route classification or hierarchy, transit agencies face challenges in decision-making, resource prioritization, and future network restructuring.

A scientifically defined route hierarchy model can address these issues by distinguishing high-priority “core” routes from secondary and feeder services. Such a model enables transport planners and policymakers to identify strategic corridors for investment, improve service delivery, and design a more resilient and adaptive public transport system.

1.2 Problem Statement

Despite growing travel demand and increasing urban complexity, Kathmandu Valley lacks a data-driven, standardized framework for classifying public transport routes. This absence hinders efforts to optimize route allocation, manage system capacity, and support multimodal integration.

With over 150 formal and informal routes crisscrossing the valley, authorities are challenged to:

- Identify which routes serve as primary backbones of the system,
- Understand which routes need rationalization, and
- Strategically expand or restructure the network.

A robust analytical framework that integrates multiple decision criteria—such as ridership, frequency, coverage, operational efficiency, and spatial equity—is essential. Without such a hierarchy, public investments risk being misallocated, and system inefficiencies are perpetuated.

1.3 Objectives

The main objective of the study is to develop a comprehensive, analytical public transport route hierarchy model for Kathmandu Valley using multicriteria decision-making (MCDM) and optimization techniques to improve operational efficiency and network planning.

Specific Objectives:

- To develop a classification framework for public transport routes using relevant performance and service indicators.
- To quantify route characteristics using data-driven metrics for 22 major routes covering the Kathmandu Valley.
- To apply MCDM and optimization algorithms to assign indicator weights and validate the classification.
- To visualize the resulting hierarchy using GIS-based spatial analysis.
- To provide policy recommendations for route restructuring and future network development.

1.4 Scope of Study

This study focuses on a core set of 22 major public transport routes that collectively cover the Kathmandu Valley, including parts of Kathmandu, Lalitpur, and Bhaktapur districts. The research emphasizes route-level analysis and classification rather than full-scale operational optimization such as scheduling or fare integration.

Key features within scope:

- Preliminary classification of routes (e.g., Long, medium, short route).
- Use of multicriteria indicators to assess each route.
- Weighting of indicators through AHP or data-driven techniques.
- Hierarchical classification of routes (e.g., primary, secondary, feeder).
- GIS mapping of the final classification for spatial analysis and visualization.
- Policy suggestions for route restructuring and improved governance.

Limitations of Study:

- Excludes detailed modeling of passenger behavior or traffic flow simulation.
- Focuses on existing routes only; does not propose entirely new routes.

1.5 Review of Analytical Route Hierarchy in Urban Public Transport Systems

A hierarchical structure in public transport networks typically includes core (trunk) routes, secondary (intermediate) services, and feeder lines. This structure facilitates better operational planning, efficient resource allocation, and passenger convenience. According to Vuchic (2005), an integrated and hierarchical system maximizes accessibility and system efficiency by aligning service levels with demand intensities.

Studies in cities such as Bogotá, Curitiba, and Ahmedabad demonstrate that clearly defined route hierarchies (e.g., BRT trunk routes with feeder services) improve operational reliability, travel time, and passenger satisfaction (Cervero, 2013; Hidalgo & Carrigan, 2010). However, many South Asian cities, including Kathmandu, lack a formal

route classification. Instead, the system evolves organically, leading to service overlaps, unserved areas, and inefficiencies. A data-driven framework for classifying routes based on demand, geography, and service characteristics remains largely unexplored in the local context.

1.5.1 Multicriteria Decision-Making (MCDM) in Transport Planning

Multicriteria decision-making techniques are increasingly used in transport planning where multiple conflicting criteria—such as cost, accessibility, service frequency, and coverage—must be balanced. MCDM methods such as Analytic Hierarchy Process (AHP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), PROMETHEE, and Entropy Weighting Method are commonly employed in transport decision-making.

For instance, AHP has been used to evaluate route options in Tehran (Nasr et al., 2012) and prioritize infrastructure projects in Delhi (Jain et al., 2020). TOPSIS and PROMETHEE have also been applied to rank transit corridors based on passenger satisfaction and operational metrics.

Despite the proven utility of MCDM methods, limited efforts have been made to use them for hierarchical classification of routes in public transport networks, particularly in contexts with informal and fragmented systems like Nepal.

1.5.2 Optimization Techniques in Public Transit Analysis

Optimization methods—such as linear programming, genetic algorithms, and simulated annealing—are often integrated with MCDM to refine weightings, validate classifications, or determine optimal configurations of transit networks.

For example, Li & Bertini (2008) used optimization to redesign bus routes and reduce passenger travel times. Similarly, Chien & Schonfeld (1998) applied optimization models to determine optimal frequencies and stop locations. More recent research incorporates machine learning and hybrid models for dynamic optimization based on real-time data (Ma et al., 2021).

While these studies focus largely on operational optimization, their frameworks are adaptable to route prioritization, particularly when combined with MCDM to ensure holistic evaluation.

1.5.3 GIS Applications in Transport Network Analysis

Geographic Information Systems (GIS) play a critical role in visualizing and analyzing transport networks. GIS enables spatial representation of route hierarchies, accessibility gaps, and travel corridors. Applications range from simple route mapping to advanced spatial modeling of coverage and service equity.

Pucher et al. (2007) highlighted GIS as a vital tool for evaluating transport equity and service coverage in developing countries. In Bangkok and Manila, GIS-based accessibility models have supported better transport planning for underserved communities.

Despite its potential, GIS has been underutilized in Kathmandu's transport planning. Most route maps remain static and disconnected from performance data. Integrating MCDM-derived classifications with GIS visualization represents a significant advancement in planning tools.

1.5.4 Case Studies from Comparable Cities

- Ahmedabad, India: The Janmarg BRT system incorporates a hierarchical design with clearly defined trunk and feeder services. Route design was informed by data on travel demand, land use, and socio-economic factors (EMBARQ, 2011).
- Dhaka, Bangladesh: Despite its chaotic transport network, recent efforts have aimed to restructure bus routes using clustering techniques and demand analysis (World Bank, 2020).
- Bogotá, Colombia: The Trans-Milenio system is a model for using MCDM and optimization for corridor selection and integration of feeder services.

These three case studies offer important insights for developing context-specific hierarchical route models, particularly for South Asian megacities like Kathmandu,

Dhaka, and Delhi. Despite varying levels of resources and governance, they share a common theme: integrating demand analysis, optimization models, and tiered route structures leads to measurable improvements in service quality, efficiency, and user satisfaction. The contextual adaptation of such models can help cities tackle chronic issues like congestion, overlapping services, and low ridership. These examples also highlight the importance of stakeholder coordination, strong institutional frameworks, and continuous data collection in achieving sustainable urban transit reforms.

1.5.5 Research Gaps Identified

- Lack of hierarchical route classification in Kathmandu's current transport planning.
- Limited application of MCDM for intra-city public route prioritization in South Asia.
- Insufficient use of GIS mapping to spatially visualize and interpret route performance.
- Need for a scalable, transparent framework that combines MCDM, optimization, and GIS for public transport restructuring.

1.6 Organization of Report

The report is structured as follows:

- **Chapter 1: Introduction**

  Presents the background and context of the study, states the research problem, outlines the study objectives, and scope, discusses MCDM applications in transport, GIS visualization, and similar frameworks from comparable cities.

- **Chapter 2: Methodology**

  Details the selection of routes, data collection, indicator development, weighting technique, classification algorithm, and GIS processes.

- **Chapter 3: Data Analysis and Findings**

Presents statistical summaries, indicator-based scores, route classification outputs, and GIS visualizations.

- **Chapter 4: Policy Implications and Recommendations**

Provides actionable insights for transport authorities and policymakers for route rationalization, investment prioritization, and future planning.

- **Chapter 5: Conclusion**

Summarizes key findings, discusses limitations, and proposes future research directions.

Chapter 2 METHODOLOGY

This chapter outlines the methodological framework adopted to formulate a public transportation route hierarchy model for Kathmandu Valley. It covers the study area's route selection, data collection and processing, development of decision criteria, application of MCDM and optimization techniques, GIS-based visualization, and validation procedures. Each methodological step is structured to ensure transparency, replicability, and rigor in line with the study's objectives.

2.1 Study Area and Route Selection

The Kathmandu Valley, comprising the districts of Kathmandu, Lalitpur, and Bhaktapur, is the focus area of this study. The region is characterized by high urban density, a rapidly growing population, and a fragmented public transport system.

The public transport routes were selected for detailed analysis based on the following criteria:

- **Coverage**

  Routes were selected that connect major population centers, employment zones, educational institutions, and commercial hubs inside the Kathmandu Valley. This ensures that the routes analyzed are representative of the valley's diverse mobility demands and offer a comprehensive picture of the transport network's reach.

- **Frequency**

  Routes operating with high or moderate trip frequencies throughout the day were prioritized. Frequent routes are generally more integral to the public transport system, and their operational patterns are critical for hierarchy classification.

- **Strategic Importance**

  Routes that include key terminals, transfer points, or corridors that intersect with multiple other routes were included. These routes often act as backbones of the network and play a central role in connectivity and passenger movement.

- **Data Availability**

  Routes were shortlisted based on the availability of consistent secondary data and feasibility of primary data collection (GPS tracking, surveys). Reliable data is essential for valid indicator computation and analysis.

Based on these parameters, A total of **22 Public Transportation routes** were selected for detailed analysis. The selection aimed to represent a balanced mix of high-demand trunk routes, moderate secondary connectors, and peripheral feeder services. These 22 routes serve as a representative sample that captures the functional diversity of Kathmandu's public transportation network. The list of the routes is shown in the table below:

Table 1: List of Selected Public Transportation Routes

Route No	Route Name	Route Type	Vehicle Type
01	Naya Buspark-Maharajgunj-Koteshwor-Banepa-Dhulikhel	Linear	Bus
02	Ringroad Circulation	Circular	Bus
03	Thankot-Kalanki-Naya Buspark-Maharajgunj-Budhanilkantha	Linear	Bus
04	Bansbari (Bhaktapur)-Suryabinayak-Koteshwor-Chabahil - Naya Buspark	Linear	Bus
05	Tikathali-Balkumari-Koteshwor-Putalisadak-Baluwatar-Kapan-Phaika	Linear	Bus
06	Balkot-Koteshwor-New Baneshwor-Tripureshwor-Kalanki-Swoyambhu	Linear	Mini Bus
07	Sundarijal-Chabahil-Gausala-Dillibazar-Bagbazar-NAC	Linear	Bus
08	Sankhu-Chabahil-Gausala-Dillibazar-Bagbazar-NAC	Linear	Bus
09	Mulpani-Pepsicola-Koteshwor-New Baneshwor-NAC	Linear	Bus
10	Tinpiple-Machhapokhari-Balaju-Lainchaur-NAC	Linear	MiniBus
11	Jhor-Nepaltar-Machhapokhari-Lainchaur-NAC	Linear	Bus
12	Lagankhel-Gwarko-Sanagaun-Lubhu-Dhungin	Linear	MiniBus

Route No	Route Name	Route Type	Vehicle Type
13	Puspalal Buspark-Kirtipur-Balkhu-Kalimati-NAC	Linear	MiniBus
14	Thankot-Kalanki-Kalimati-NAC	Linear	MiniBus
15	Lagankhel-Satdobato-Harisiddhi-Godawari	Linear	MiniBus
16	Naya Buspark-Gongabu-Putalisadak-Purano Baneshwor-Sinamangal	Linear	MiniBus
17	Raniban-Dhungedhara-Balaju-Lainchaur-NAC	Linear	MiniBus
18	Budhanilkantha-Maharajgunj-Lazimpat-Ratnapark	Linear	Bus
19	Goldhunga-Machhapokhari-Balaju-Lainchaur-NAC	Linear	MiniBus
20	Lagankhel-Satdobato-Thecho-Chapagaun-Takhel Chautara	Linear	MiniBus
21	Chandeshwori-Tokha-Samakhusi-Lainchaur-NAC	Linear	Micro
22	Lagankhel-Jawalakhel-Maitighar-Ratnapark	Linear	Micro

These routes cover a range of urban contexts—from dense commercial zones to semi-urban peripheries. This ensures a comprehensive understanding of network performance across service types. A GIS-based map was developed to illustrate the spatial distribution of these 22 selected routes as shown in figure below:

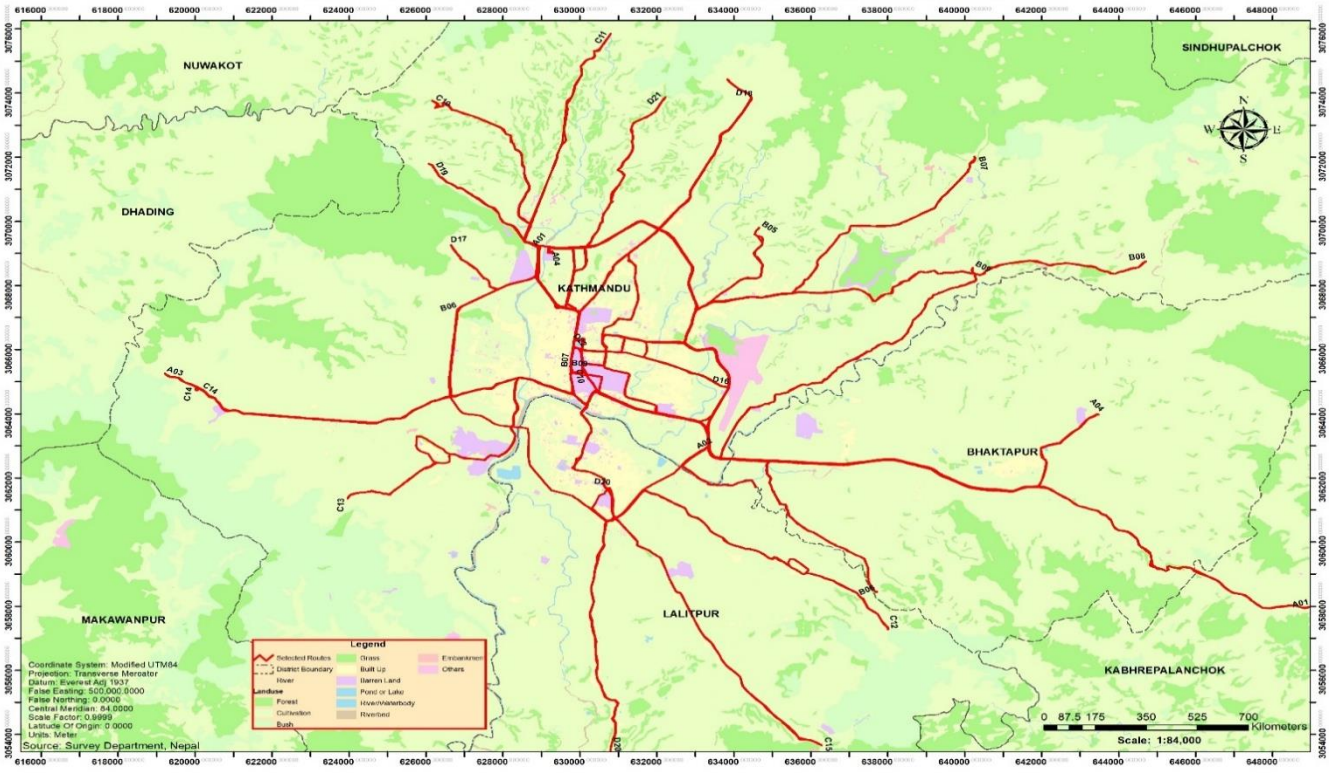


Figure 1:Spatial Distribution of Selected Bus Routes in Kathmandu Valley

2.2 Data Collection

Both primary and secondary data sources were utilized to build a comprehensive dataset:

2.2.1 Primary Data

- **Boarding Alighting Data**

  To capture passenger movement patterns and understand route-level demand, a structured boarding and alighting survey was conducted across all 22 selected public transport routes in Kathmandu Valley. The survey was carried out manually by trained enumerators positioned inside public buses and minibuses. Data was collected at three distinct time periods of the day—morning peak, day off-peak and evening peak—to account for temporal variation in ridership. Furthermore, each route was surveyed in both directions of travel (origin to destination and vice versa) to capture directional flow asymmetry.

  Enumerators recorded the number of passengers boarding and alighting at each designated stop (male and female separately) during the observation period, along with stop name, its geolocation (latitude and longitude), arrival and departure time at each stops in the preset mobile form in Epicollect5 platform.

  This data enabled the creation of stop-wise passenger load profiles and identification of high-demand nodes, peak-hour crowding, and potential bottlenecks. The survey approach ensured consistency across all routes and times, allowing comparative analysis and integration with GIS-based route visualization.

  The sample data sheet of the Boarding Alighting Survey is presented in following screenshot.

Route_Name	RoundTrip	Route_Direction	Stops_No	Stop_Name	Std_Latitude	Std_Longitude	Board_Male	Bord_Female	Alight_male	Alight_Femal	Board_Total	Alight_Total	Net_Males	Net_Fema	Total_Pax	Arrival Time	Departure Time
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	1	Thali Busstop	27.726725	85.419809	0	0	0	0	0	0	0	0	0	8:43:01 AM	8:52:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	2	Maiti Nepal Chowk	27.720074	85.409135	1	0	0	0	1	0	1	0	1	8:54:32 AM	8:54:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	3	Mulpani Buspark	27.715713	85.406013	2	1	0	0	3	0	3	1	4	8:57:21 AM	9:00:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	4	Srijanatol	27.708546	85.400703	1	1	0	0	2	0	4	2	6	9:02:22 AM	9:02:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	4	Srijanatol	27.708546	85.400703	1	0	0	0	1	0	5	2	7	9:03:28 AM	9:03:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	5	Mulpani, Pipalboat	27.706424	85.394287	4	5	0	0	9	0	9	7	16	9:05:05 AM	9:09:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	5	Mulpani, Pipalboat	27.706424	85.394287	1	1	0	0	2	0	10	8	18	9:10:38 AM	9:10:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	6	Mulpani Pratikshyalaya	27.701585	85.385591	4	2	0	0	6	0	14	10	24	9:14:36 AM	9:15:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	7	Bista Gaun	27.699524	85.383222	5	0	0	0	5	0	19	10	29	9:17:12 AM	9:17:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	8	Hajurko Dhara	27.697392	85.380743	0	1	1	1	1	2	18	10	28	9:18:39 AM	9:18:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	9	Harahara Mahadev Chowk	27.696561	85.379757	2	1	0	1	3	1	20	10	30	9:19:21 AM	9:19:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	10	Bahra Shutter	27.696243	85.376933	2	5	0	0	7	0	22	15	37	9:20:20 AM	9:22:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	11	Lahure Chowk	27.695935	85.374918	1	3	0	0	4	0	23	18	41	9:23:01 AM	9:23:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	11	Lahure Chowk	27.695935	85.374918	0	2	0	0	2	0	23	20	43	9:23:54 AM	9:24:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	12	Suncity Chowk	27.694063	85.370997	1	2	0	0	3	0	24	22	46	9:24:35 AM	9:26:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	12	Suncity Chowk	27.694063	85.370997	0	1	0	0	1	0	24	23	47	9:26:56 AM	9:27:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	13	Sunrise Stop	27.692947	85.367328	2	4	0	0	6	0	26	27	53	9:27:53 AM	9:29:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	13	Sunrise Stop	27.692947	85.367328	0	0	1	0	0	1	25	27	52	9:29:36 AM	9:29:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	14	Pepsicola Chowk	27.689037	85.360473	1	1	0	0	2	0	26	28	54	9:31:13 AM	9:31:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	14	Pepsicola Chowk	27.689037	85.360473	0	0	2	2	0	4	24	26	50	9:34:03 AM	9:34:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	14	Pepsicola Chowk	27.689037	85.360473	1	1	0	0	2	0	25	27	52	9:35:39 AM	9:36:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	15	Chappro Jadibuti	27.684744	85.356699	1	0	1	0	1	1	25	27	52	9:37:07 AM	9:37:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	16	Jadibuti North	27.676556	85.352883	0	0	2	2	0	4	23	25	48	9:39:07 AM	9:41:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	16	Jadibuti North	27.676556	85.352883	0	0	1	0	0	1	22	25	47	9:43:37 AM	9:49:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	17	Koteshwor East	27.67788	85.349504	0	0	3	4	0	7	19	21	40	9:50:52 AM	9:52:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	18	Koteshwor North	27.679864	85.349697	7	0	4	0	7	4	22	21	43	9:54:06 AM	9:54:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	19	Tinkune West	27.686282	85.345098	2	1	2	0	3	2	22	22	44	9:56:51 AM	9:59:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	20	Shantinagar	27.687068	85.341979	0	1	2	0	1	2	20	23	43	9:59:49 AM	10:00:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	20	Shantinagar	27.687068	85.341979	2	0	0	1	2	1	22	22	44	10:01:10 AM	10:01:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	21	New Baneshwor Chowk	27.688555	85.334726	3	2	2	3	5	5	23	21	44	10:02:28 AM	10:04:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	21	New Baneshwor Chowk	27.688555	85.334726	0	2	0	0	2	0	23	23	46	10:05:52 AM	10:06:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	22	Bijulibazar	27.690536	85.327871	1	0	2	0	1	2	22	23	45	10:06:50 AM	10:07:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	22	Bijulibazar	27.690536	85.327871	1	3	0	1	4	1	23	25	48	10:07:55 AM	10:09:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	23	Sahidgate West	27.699487	85.315464	0	0	4	1	0	5	19	24	43	10:20:20 AM	10:20:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	Mulpani-NAC	24	NAC	27.701577	85.313506	0	0	19	24	0	43	0	0	0	10:22:20 AM	10:23:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	NAC-Mulpani	1	NAC	27.701577	85.313506	9	5	0	0	14	0	9	5	14	10:24:32 AM	10:26:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	NAC-Mulpani	2	Babarmahal	27.692812	85.323658	1	1	1	0	2	1	9	6	15	10:41:50 AM	10:42:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	NAC-Mulpani	3	Bijulibazar	27.690536	85.327871	1	0	0	0	1	0	10	6	16	10:43:45 AM	10:44:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	NAC-Mulpani	3	Bijulibazar	27.690536	85.327871	1	1	0	0	2	0	11	7	18	10:44:32 AM	10:44:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	NAC-Mulpani	4	New Baneshwor Chowk	27.688555	85.334726	0	1	1	0	1	1	10	8	18	10:45:44 AM	10:48:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	NAC-Mulpani	5	Shantinagar	27.687068	85.341979	2	2	0	0	4	0	12	10	22	10:48:51 AM	10:51:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	NAC-Mulpani	5	Shantinagar	27.687068	85.341979	2	0	1	1	2	2	13	9	22	10:51:57 AM	10:52:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	NAC-Mulpani	6	Tinkune West	27.686282	85.345098	2	0	0	1	2	1	15	8	23	10:53:06 AM	10:54:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	NAC-Mulpani	7	Koteshwor North	27.679864	85.349697	2	3	1	2	5	3	16	9	25	10:56:46 AM	11:00:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	NAC-Mulpani	8	Jadibuti West	27.675516	85.351571	1	3	1	0	4	1	16	12	28	11:01:22 AM	11:04:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	NAC-Mulpani	9	Jadibuti North	27.676556	85.352883	4	3	0	0	7	0	20	15	35	11:05:19 AM	11:06:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	NAC-Mulpani	10	Chappro Jadibuti	27.684744	85.356699	1	0	0	0	1	0	21	15	36	11:08:45 AM	11:08:00 AM
Mulpani-Koteshwor-NAC	1st (Morning Peak)	NAC-Mulpani	11	Pepsicola Chowk	27.689037	85.360473	0	1	0	0	1	0	21	16	37	11:12:09 AM	11:12:00 AM

Figure 2: Sample Datasheet of Boarding Alighting Survey

- **Route Tracking**

Field-based route tracking was carried out for all 22 selected public transport routes to ensure spatial accuracy and data authenticity. Each route was tracked using GPS-enabled mobile applications during regular operational hours, covering both directions (up and down). Enumerators traveled on-board from origin to destination, marking real-time location data at intervals of 5–10 seconds, especially at major intersection and stops. The collected GPS traces were later exported in GPX/CSV format and integrated into GIS software for further digitization. This ground-truthing process ensured that route alignment and stop positioning matched real-world conditions, complementing digital base maps and improving the precision of subsequent spatial analysis.

The route tracking and onboard boarding alighting survey was carried out parallelly.

- **Structured interviews with operators and passengers**

  To gain firsthand insights into the operational characteristics and user experiences of the selected public transport routes, structured interviews were conducted with both vehicle operators and passengers. The interviews followed a standardized set of open- and close-ended questions designed to gather consistent, comparable data across different stakeholders.

  For operators (drivers and conductors), the questions focused on route navigation, stop timing accuracy, traffic bottlenecks, peak-hour challenges, and perceptions of route overlap or inefficiency. For passengers, the emphasis was on travel time reliability, wait time, crowding, fare affordability, and route accessibility.

2.2.2 Secondary Data

- Official government records by the Department of Transport Management (DoTM) and Kathmandu Metropolitan City (KMC) provided the details of registered routes, licenses, number of vehicles per route, and legal designations.
- The insight into formal scheduling, operational hours, and service frequency for various routes were collected from the operators and their field staffs.
- Satellite imagery and open-source transport datasets: Sources like OpenStreetMap (OSM) were used for spatial alignment, route tracing, and stop verification.
- Various Reports related to the Public Transportation in Kathmandu Valley were studied to gain the overview of existing routes and the passenger demand in those routes

The Data collected covered the following attributes:

- **Route Length:**

Measured using GPS tracking during field route tracing. It indicates the total physical distance (in kilometers) covered from the route's origin to its destination, accounting for real-world road curves and alignments. Longer routes typically reflect trunk or cross-city services, while shorter ones serve local or feeder roles.

- **Stop Spacing:**

Calculated as the average distance between consecutive stops. It is derived by dividing the total route length by the number of stops minus one. This metric is critical in determining stop density, influencing travel speed, accessibility, and operational efficiency.

- **Stop Location:**

GPS coordinates (latitude/longitude) of all bus stops were collected through field surveys and cross-referenced with municipal records. These spatial points enabled mapping of boarding/alighting activity and analysis of coverage gaps. Each stop was classified as major, intermediate, or local based on passenger load and network connectivity.

- **Travel Time per Trip:**

Recorded through onboard observations and time-stamped GPS logs during peak and off-peak periods. Variations between the two helped assess reliability and congestion impacts. The metric is useful for computing schedule adherence and evaluating average route speed.

- **Passenger Demand at Each Stop:**

Collected via boarding–alighting surveys conducted in both directions during morning, mid-day, and evening time periods. The net passenger load (boardings minus alighting) was used to develop stop-wise ridership profiles and demand intensity maps.

- **Daily Ridership:**

Estimated by extrapolating boarding counts from sampled time windows across full-day service hours. Secondary data from operators and published reports were also used to validate estimates. It reflects route popularity and utilization levels, and directly influences service planning.

- **Fleet Size per Route:**

Number of vehicles (buses or microbuses) regularly assigned to each route, obtained from operator interviews and field observation. This factor determines the maximum service capacity and informs frequency computation.

- **Frequency and Headway:**

Frequency indicates the number of trips per hour, while headway is the time gap between consecutive vehicles. These were derived from timetable analysis, operator feedback, and observed intervals during field tracking. Together, they reflect service availability and attractiveness to users.

- **Operational Hours:**

Total duration (in hours) during which vehicles operate on a route each day. Start and end times were recorded from first and last departures observed during the survey. Shorter operational windows can limit access for late-night or early-morning commuters.

All data were compiled in spreadsheet format and cleaned before being spatially aligned using GIS-compatible formats (e.g., shapefiles, GeoJSON).

2.3 Route Naming and Coding Convention

To maintain consistency, streamline data processing, and ensure clear identification during analysis, a standardized coding system was adopted for all 22 public transport routes included in this study. This approach facilitated efficient referencing of each route throughout various stages of data handling, descriptive analysis, visualization, and classification.

Each route was assigned a unique alphanumeric code, structured as follows:

- Prefix “A, B,C,D” indicates the tier of inclusion of the route in the analytical study.

- The two-digit numerical identifier following the prefix (e.g., "01", "02", "17") represents the sequential number of the route as cataloged during data collection.

- The fourth letter, after the sequential number of route denotes the direction of the route. The following table shows the direction configuration of the public transportation routes.

Table 2: Coding Convention for Direction and Trip

Direction Code	Direction Configuration	Trip Code	Trip Configuration
A	East to West	M	Morning Peak
B	West to East	D	Day Off-Peak
C	North to South	E	Evening Peak
D	South to North		
CL	Clockwise Direction		

- In cases where subvariants of a route (such as Trip time) were present, an additional alphabetic suffix (e.g. M, D, E) was appended to distinguish among variants of the same core route.

For example:

- A01 refers to the first route analyzed in the study.
- A01A and A01B may represent the same route operated in different directions i.e East-West direction and West-East Direction respectively
- A17MA and A17DC represents the Morning Peak trip in East-West direction and Day Off-Peak in North-South Direction of the seventeenth route in the analysis.

This coding system supports multiple advantages:

- It enables simplified labeling in charts, maps, and tables without using lengthy route names.
- It avoids ambiguity where routes may have similar or overlapping names in colloquial use.
- It provides a scalable and expandable structure, allowing for new routes or sub-routes to be added without disrupting the existing classification.
- It facilitates programmatic sorting and filtering, particularly in Python- or Excel-based data analysis and visualization scripts.

Additionally, this route coding was used consistently in GIS mapping layers, heatmaps, and tabulated indicator summaries, making it easier for planners and stakeholders to cross-reference analytical results with spatial representations.

2.4 Preliminary Classification of Routes

To better understand and optimize the urban bus network, the selected routes were classified into a four-tier hierarchy short, medium-short, medium-long and long routes based on route length, measured in kilometers, which is a fundamental metric that significantly influences route typology, travel time, operational costs, and coverage area. By classifying routes hierarchically based solely on their total length, planners can distinguish between long-haul trunk services and short, localized routes.

- **Operational Planning**: Longer routes typically require more vehicles, greater fuel and labor costs, and buffer times to maintain reliability.

- **Service Strategy**: Short routes often serve local feeders or circulate within neighborhoods; longer routes cover main corridors or inter-municipal links.

- **Network Hierarchy**: Differentiating based on length helps in identifying the core structure of the transit network and planning integration points.

2.4.1 Classification Tiers

To better understand the operational characteristics and service roles of the 22 selected public bus routes, a preliminary classification based on total route length was applied. This approach aids in differentiating between core and supporting services, guiding route planning, scheduling, fleet allocation, and investment prioritization. The routes were grouped into four distinct tiers: up to 10 km, 10–15 km, 15–20 km, and greater than 20 km.

- **Tier A – Long Routes (> 20 km):**

Long routes represent primary trunk or regional connections that span across multiple urban and peri-urban zones. These routes serve the highest number of passengers over the longest distances, often connecting city centers to distant municipalities or emerging growth areas. Due to their extended length, they face the highest exposure to traffic congestion and operational unpredictability. Such routes require robust infrastructure support, including bus bays, express service options, and integration with terminals or multimodal hubs. Long routes are integral to regional mobility and are strong candidates for dedicated lane implementations or BRT conversion in high-demand corridors. The following 4 routes are classified under Tier-A.

Table 3: List of Tier-A Public Transportation Routes

Tier	Route Code	Route Name	Route Length
A	**A01**	Naya Buspark-Maharajgunj-Koteshwor-Banepa-Dhulikhel	**36.24**
	A02	Ringroad Circulation	**27.44**
	A03	Thankot-Kalanki-Naya Buspark-Maharajgunj-Budhanilkantha	**23.55**
	A04	Bansbari (Bhaktapur)-Suryabinayak-Koteshwor-Chabahil -Naya Buspark	**23.85**

These routes are shown in GIS maps as follow:

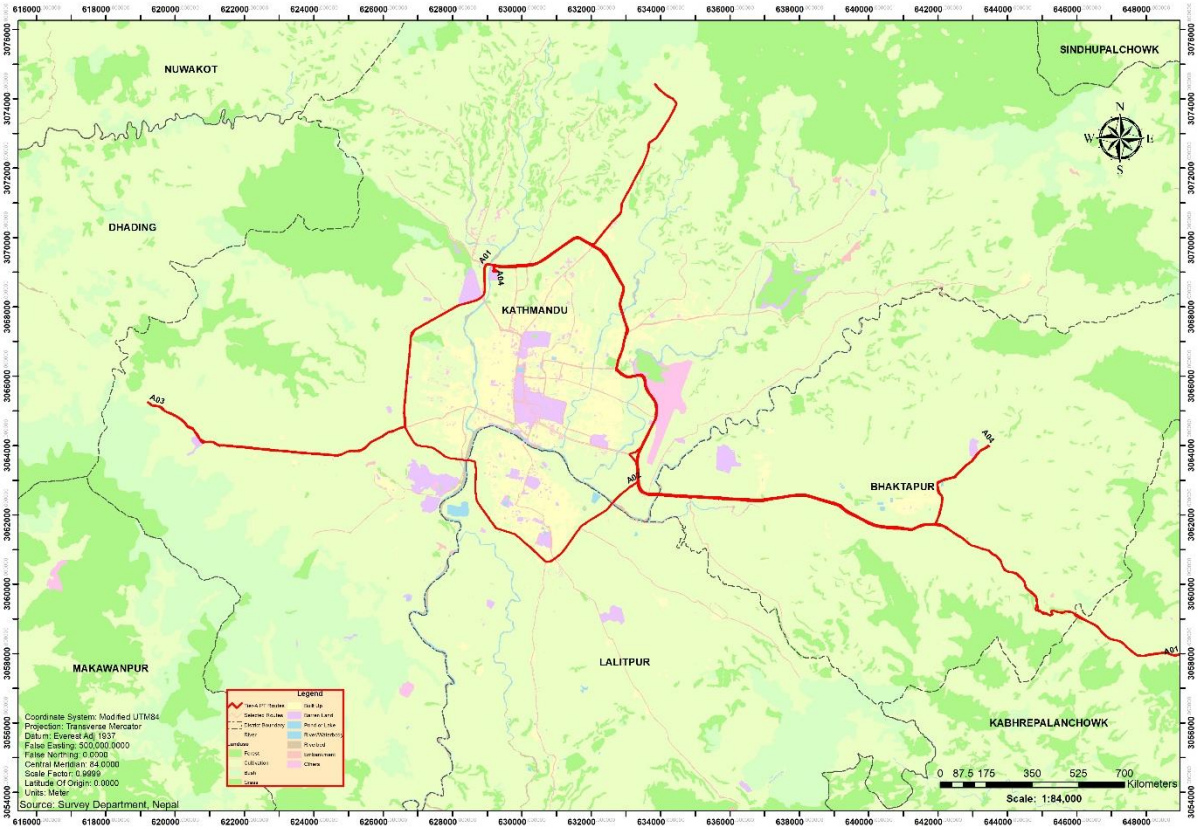


Figure 3: Tier-A Public Transportation Routes Map

- **Tier B – Medium-Long Routes (15 km-20 km):**

Routes in this tier are typically classified as strategic trunk lines that connect the urban core to outer areas or satellite towns. These medium-long routes are high-capacity corridors that witness substantial passenger demand during peak hours. They often function as backbones of the city's transit network, supporting both direct travel and transfer-based journeys. Due to their longer lengths, they require careful attention to travel time variability, schedule adherence, and fleet utilization. Investments in intelligent transportation systems (ITS), signal priority, or partial lane segregation may be necessary to maintain efficiency and reliability along these corridors. Out of 22 routes, 5 routes are classified under tier-B routes which are shown in table as well as figure below:

Table 4: List of Tier-B Public Transportation Routes

Tier	Route Code	Route Name	Route Length
B	**B05**	Tikathali-Balkumari-Koteshwor-Putalisadak-Baluwatar-Kapan-Phaikaa	**19.64**
	B06	Balkot-Koteshwor-New Baneshwor-Tripureshwor-Kalanki-Swoyambhu	**18.23**
	B07	Sundarijal-Chabahil-Gausala-Dillibazar-Bagbazar-NAC	**15.55**
	B08	Sankhu-Chabahil-Gausala-Dillibazar-Bagbazar-NAC	**18.50**
	B09	Mulpani-Pepsicola-Koteshwor-New Baneshwor-NAC	**15.66**

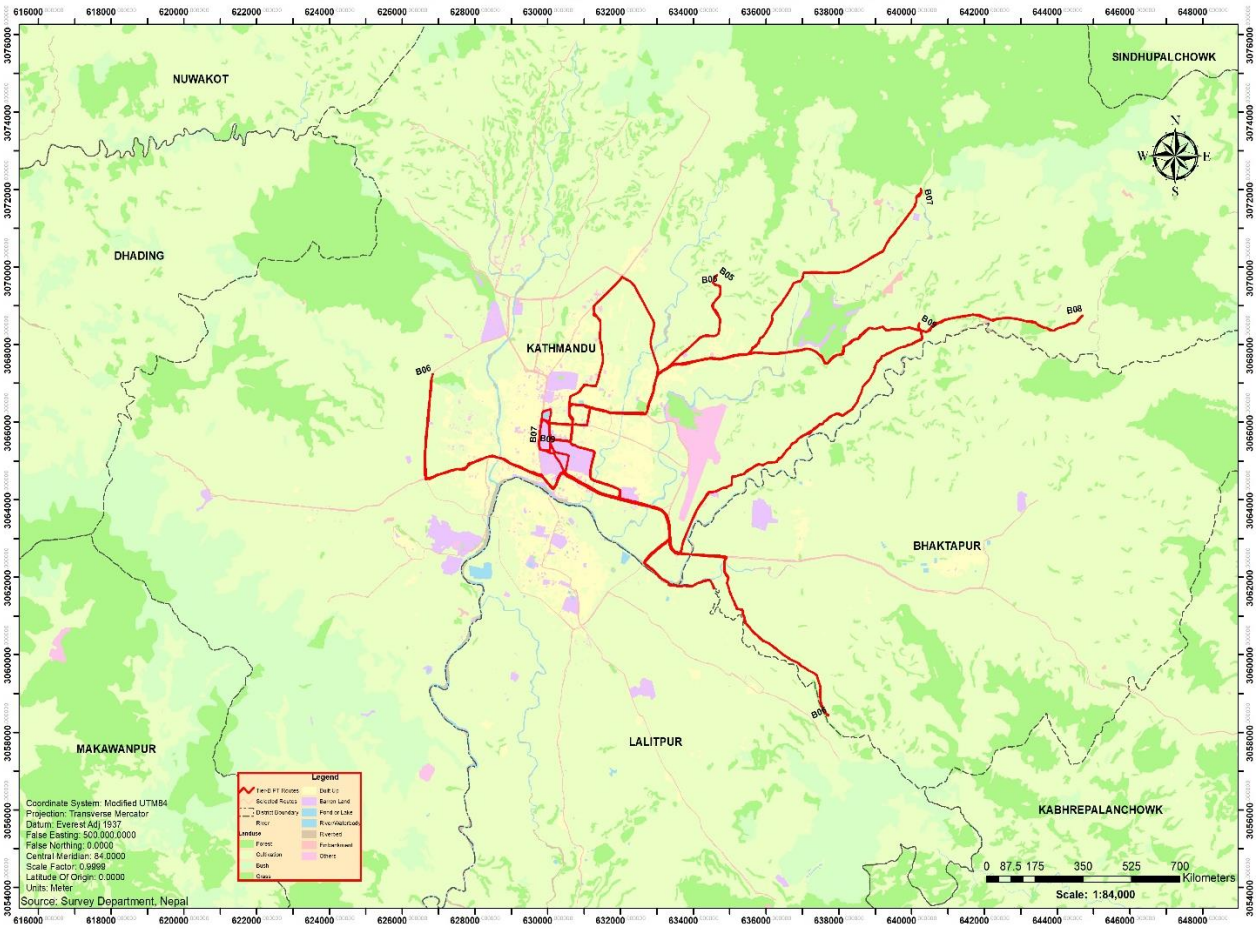


Figure 4: Tier-B Public Transportation Routes Map

- **Tier C – Medium-Short Routes (10 km-15 km):**

Medium-short routes strike a balance between accessibility and operational reach. These routes usually connect multiple neighborhoods or extend slightly beyond local boundaries. They are critical in linking secondary activity centers, educational institutions, or industrial zones with residential areas. Medium-short routes offer moderate trip durations and frequencies, allowing for a cost-effective service model. Their operational planning often involves optimization of headways and stop placement to reduce travel time while preserving accessibility. These routes also serve as feeders to higher-tier corridors, enhancing system integration. The following 6 routes out of 22 routes are classified under Tier-C.

Table 5: List of Tier-C Public Transportation Routes

Tier	Route Code	Route Name	Route Length
C	**C10**	Tinpiple-Machhapokhari-Balaju-Lainchaur-NAC	**11.44**
	C11	Jhor-Nepaltar-Machhapokhari-Lainchaur-NAC	**12.28**
	C12	Lagankhel-Gwarko-Sanagaun-Lubhu-Dhungin	**10.54**
	C13	Puspalal Buspark-Kirtipur-Balkhu-Kalimati-NAC	**11.55**
	C14	Thankot-Kalanki-Kalimati-NAC	**12.31**
	C15	Lagankhel-Satdobato-Harisiddhi-Godawari	**10.14**

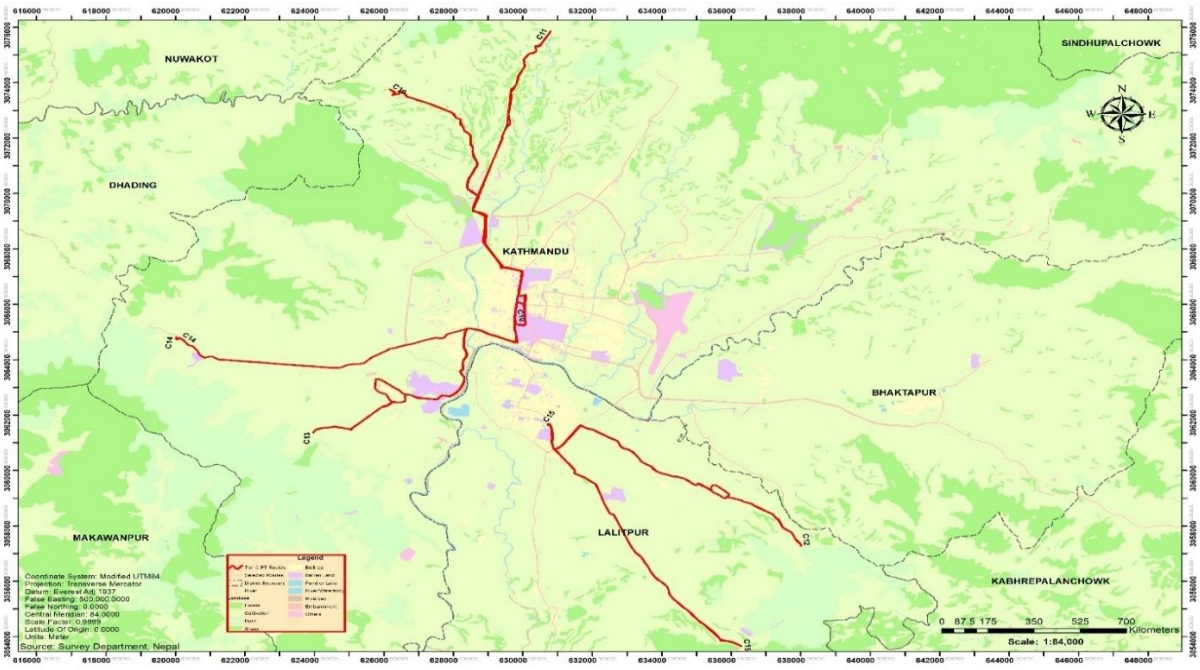


Figure 5: Tier-C Public Transportation Routes Map

- **Tier D – Short Routes (≤ 10 km):**

Routes within this category are relatively short and primarily serve as feeder or local circulator services. These routes typically operate within a single municipality or ward, connecting residential neighborhoods to nearby commercial centers or main transport hubs. Due to their compact nature, they are characterized by higher stop densities, shorter trip durations, and often operate with smaller vehicle fleets. These routes enhance last-mile connectivity and are essential in providing accessibility in densely populated urban areas. However, they may also be vulnerable to frequent stopping delays and require precise scheduling to maintain service reliability.7 out of 22 are classified as tier-D routes as shown in table below:

Table 6: List of Tier-D Public Transportation Routes

Tier	Route Code	Route Name	Route Length
D	**D16**	Naya Buspark-Gongabu-Putalisadak-Purano Baneshwor-Sinamangal	**9.85**
	D17	Raniban-Dhungedhara-Balaju-Lainchaur-NAC	**6.94**
	D18	Budhanilkantha-Maharajgunj-Lazimpat-Ratnapark	**9.55**
	D19	Goldhunga-Machhapokhari-Balaju-Lainchaur-NAC	**8.70**
	D20	Lagankhel-Satdobato-Thecho-Chapagaun-Takhel Chautara	**9.90**
	D21	Chandeshwori-Tokha-Samakhusi-Lainchaur-NAC	**9.96**
	D22	Lagankhel-Jawalakhel-Maitighar-Ratnapark	**5.81**

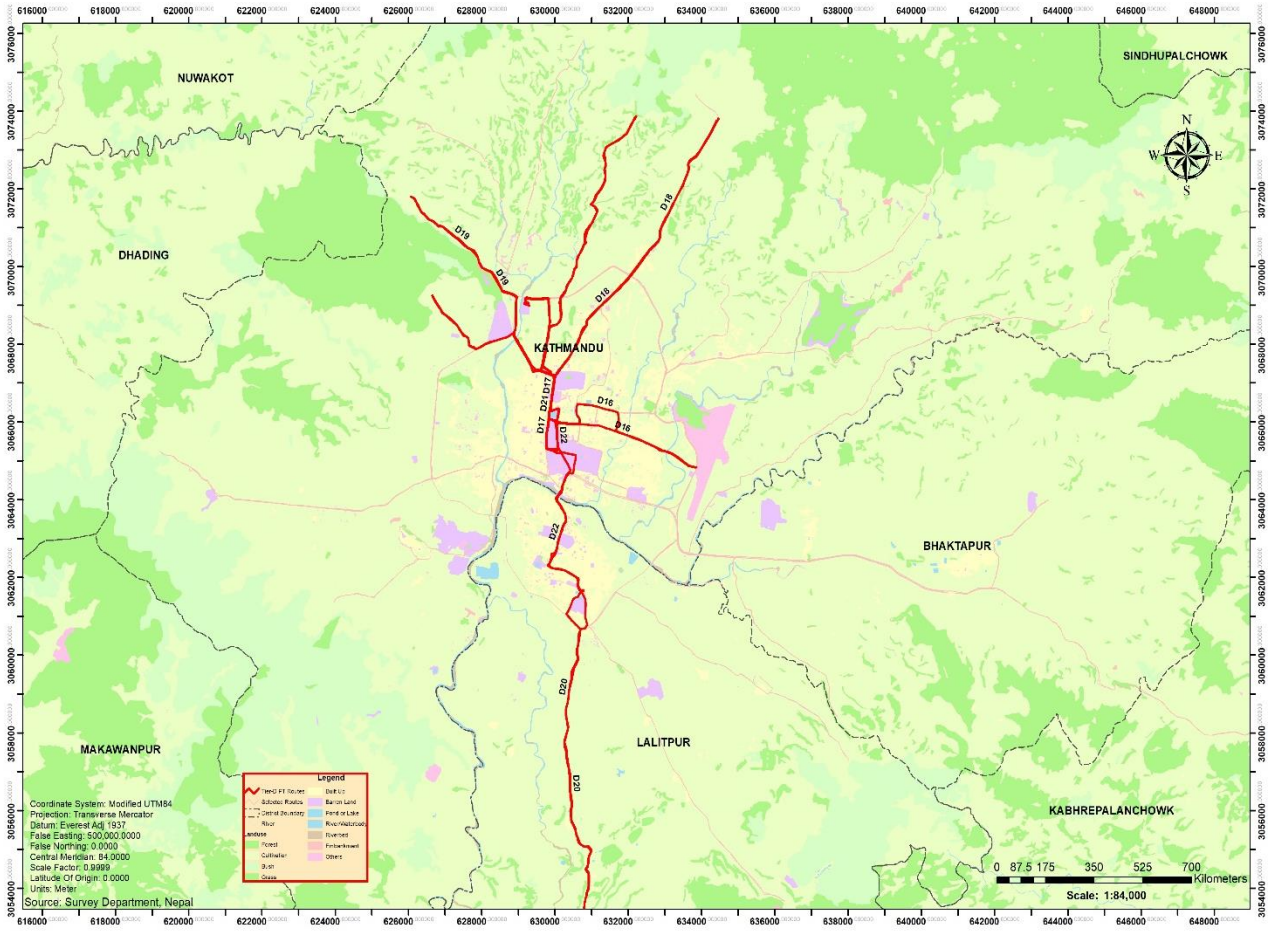


Figure 6: Tier-D Public Transportation Routes Map

This length-based classification not only reveals the operational nature of each route but also facilitates targeted interventions in route restructuring, scheduling, and infrastructure upgrades. Shorter routes are ideal for improving access and coverage, while longer routes demand strategic investments for speed, capacity, and system integration. This stratification also aligns with global best practices in tiered network design and supports the development of a sustainable and efficient urban transport system.

2.5 Indicator Selection

Indicators were selected based on literature and expert input to comprehensively assess route performance, service quality, and network integration.

- **Route Length (km)**

  Route length measures the total distance from the origin to the destination of a bus route. Longer routes often indicate wider spatial coverage and are typically used for connecting core urban centers with peripheral zones. However, they may also introduce operational challenges such as increased likelihood of delays, higher fuel consumption, and greater exposure to congestion and variability in service reliability.

- **Daily Ridership**

  Daily ridership captures the total number of passengers who board a vehicle on a given route each day. It is a direct indicator of route popularity and demand. High ridership values are generally associated with economically active corridors or high-density settlements, and they reflect both the social utility and financial sustainability of the service. Low ridership may signal poor connectivity or underutilization.

- **Number of Stops**

  The number of stops reflects how frequently a vehicle halts along a route for passenger boarding and alighting. Routes with a higher number of stops offer better accessibility and user convenience, particularly in densely populated areas. However, excessive stops may reduce average travel speed, increase travel time, and affect overall service efficiency, especially on routes intended for rapid or long-distance commuting.

- **Vehicle Load Ratio**

  This ratio compares the number of passengers onboard to the total seating or carrying capacity of a vehicle. A value above 1 implies overcrowding, potentially compromising passenger comfort and safety, while values significantly below 1 suggest inefficiency or excess capacity. This indicator is

essential for evaluating operational balance, service quality, and potential need for service scaling or fleet adjustment.

- **Stop Density (stops/km)**

  Stop density indicates the average number of stops per kilometer along a route. High stop density is typically found in inner-city or highly populated areas, improving access and walkability. However, it can negatively impact travel time and operational speed. Low stop density suits express services or routes covering longer distances, where speed is prioritized over granular access.

- **Average Headway (minutes)**

  Average headway refers to the time interval between two consecutive vehicles on the same route. Shorter headways mean higher service frequency, leading to reduced passenger wait times and better quality of service. Longer headways, conversely, may indicate limited availability and lower passenger convenience, often discouraging usage during off-peak periods or on less prioritized routes.

- **Overlap Ratio with Other Routes**

  The overlap ratio quantifies how much a given route shares its path with other bus or transit routes. High overlap can lead to redundancy, congestion, and inefficient use of public transport infrastructure. Conversely, moderate overlap may enhance service redundancy and transfer convenience. This metric is useful for optimizing network coverage and reducing unnecessary duplication of services.

- **Travel Time Variability**

  Travel time variability reflects the degree to which journey durations on the same route fluctuate across different trips or time periods. High variability is often caused by traffic congestion, signal delays, or inconsistent driver behavior, undermining schedule reliability. Routes with low variability are

more predictable and user-friendly, particularly for time-sensitive commuters who depend on consistent arrival times.

- **Connectivity Index**

  The connectivity index measures the number of accessible transfer points along a route, either to other bus routes or to different transport modes. A high connectivity index enhances multimodal integration, passenger flexibility, and system-wide efficiency. It is especially important in polycentric cities or transit networks where route interdependence supports greater overall accessibility and reduces total travel time.

2.6 Weight Assignment using Analytical Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a structured decision-making methodology used to derive the relative importance (weights) of various criteria. The method combines both quantitative rigor and expert judgment, making it particularly valuable when data-driven and experiential inputs need to be integrated.

2.6.1 Fuzzy Analytic Hierarchy Process (Fuzzy AHP)

The Fuzzy Analytic Hierarchy Process (Fuzzy AHP) is an advanced form of AHP that incorporates fuzzy logic to handle uncertainty and incomplete information in expert judgments. Whereas traditional AHP uses precise numerical values for pairwise comparisons, Fuzzy AHP allows experts to express their preferences using ranges or linguistic terms (e.g., equal, moderate, strong), which are converted into Triangular Fuzzy Numbers (TFNs). This makes the method more realistic and better suited to decision-making.

- **Expert Consultation and Pairwise Comparison**

The initial step involves gathering expert judgments on the relative importance of each pair of criteria. These judgments are not expressed as single numbers but as triangular fuzzy numbers (TFNs) to capture uncertainty. A TFN is defined by a lower bound, a most likely value, and an upper bound.

Mathematically, a fuzzy comparison is represented as:

$$\tilde{a}_{ij} = (l_{ij}, m_{ij}, u_{ij})$$

- $\tilde{a}_{ij}$ is the fuzzy number representing the importance of criterion i over criterion j.
- l_{ij} is the lower bound.
- m_{ij} is the most likely value.
- u_{ij} is the upper bound.

This approach allows the model to account for the natural uncertainty in human judgment.

- **Construct Fuzzy Pairwise Comparison Matrix**

All expert judgments are compiled into a square matrix, where rows and columns represent the criteria. The diagonal elements, which compare a criterion to itself, are always equal to (1, 1, 1). The lower-triangle elements are calculated as the reciprocal of the upper-triangle elements to ensure consistency.

The reciprocal of a TFN is computed as:

$$\tilde{a}_{ji} = \left(\frac{1}{u_{ij}}, \frac{1}{m_{ij}}, \frac{1}{l_{ij}}\right)$$

- n is the total number of criteria.
- $\tilde{a}_{ii} = (1, 1, 1)$ for all i.

This matrix systematically organizes subjective expert judgments and forms the basis for subsequent computations.

- **Compute Row Fuzzy Geometric Means**

For each row of the fuzzy matrix, a fuzzy geometric mean is calculated. This step summarizes the overall priority of a criterion relative to all others. The geometric mean is preferred over the arithmetic mean because it better handles the multiplicative nature of pairwise comparisons in AHP.

The fuzzy geometric mean for criterion i is given by:

$$\tilde{GM}_i = \left(\left(\prod_{j=1}^{n} l_{ij} \right)^{1/n}, \left(\prod_{j=1}^{n} m_{ij} \right)^{1/n}, \left(\prod_{j=1}^{n} u_{ij} \right)^{1/n} \right)$$

- $\tilde{GM}_i$ is the geometric mean for criterion i.
- l_{ij}, m_{ij}, u_{ij} are the TFN elements of row i.
- n is the number of criteria.

- **Normalize Fuzzy Weights**

The fuzzy geometric means are then normalized to produce fuzzy weights that, in their crisp form, sum to 1. This normalization process ensures the weights are comparable and proportionally reflect each criterion's relative importance.

The normalized fuzzy weight $\tilde{w}_i$ for criterion i is calculated as:

$$\tilde{w}_i = \left(\frac{l_i}{\sum_{k=1}^{n} u_k}, \frac{m_i}{\sum_{k=1}^{n} m_k}, \frac{u_i}{\sum_{k=1}^{n} l_k} \right)$$

- $\tilde{w}_i$ is the fuzzy weight of criterion i.
- l_i, m_i, u_i are the fuzzy geometric means of criterion i.
- $\sum l_i, \sum m_i, \sum u_i$ are the sums of the lower, middle, and upper bounds across all criteria, respectively.

- **Defuzzification**

After normalization, the fuzzy weights are converted into crisp, single-value weights for practical application. The centroid method is commonly used for this conversion.

The crisp weight w_i for criterion i is calculated as:

$$w_i = \frac{l_i + m_i + u_i}{3}$$

w_i is the final crisp weight of criterion i.

This step converts the fuzzy range into a single representative value, simplifying the scoring of alternatives. The final crisp weights are then normalized so that their sum equals 1.

- **Optional Consistency Check**

To verify the logical consistency of expert judgments, a standard AHP consistency check can be performed using the middle values (m_{ij}) from the TFNs. The Consistency Ratio (CR) indicates whether the judgments are acceptably consistent (typically, CR ≤ 0.10).

The formulas for the consistency check are:

$$CR = \frac{CI}{RI}, \quad CI = \frac{\lambda_{max} - n}{n - 1}$$

- λ_{max} is the maximum eigenvalue of the AHP matrix.
- CI is the consistency index.
- RI is the random index from Saaty's table.

- **Apply Weights to Alternatives**

The final crisp weights are applied to evaluate and rank alternatives. After normalizing the criteria values for each alternative, the overall score is calculated as a weighted sum.

The weighted score of each alternative r is:

$$Score(r) = \sum_{k=1}^{n} w_k \cdot s_k(r)$$

- $Score(r)$ is the overall score of alternative r.
- w_k is the weight of criterion k.
- $s_k(r)$ is the normalized performance of alternative r on criterion k.

Alternatives are then ranked based on their total weighted score.

2.7 GIS Based Visualization

Geographic Information System (GIS) tools were utilized to spatially analyze and communicate the structure, coverage, and performance of the selected public transport routes. QGIS, an open-source GIS platform, was employed due to its flexibility, compatibility with GPS data, and ability to handle multiple data layers. The GIS-based approach enabled the conversion of raw data such as GPS tracks, survey points, and demographic layers—into interactive maps that support both technical analysis and stakeholder engagement.

- **Route Digitization**

  The first step in the GIS workflow involved route digitization. Using GPS tracks collected during field route tracing, each bus route was accurately mapped over existing base maps. This process included snapping GPS traces to the road network and correcting spatial inaccuracies, especially in areas where satellite signals were weak or urban obstructions occurred. The digitized routes were converted into polyline shapefiles, allowing for spatial queries

and integration with attribute data such as route length, number of stops, and frequency. This geospatial representation provided a solid foundation for advanced spatial analysis and thematic mapping.

- **Symbolization**

  After digitizing the routes, a clear symbolization strategy was applied to visually differentiate the classified route tiers. Core routes were assigned bold red lines, secondary routes were styled with medium-weight orange lines, and feeder routes were represented using thin green lines. This symbolic hierarchy allowed easy interpretation of the route importance and roles within the transit network. Additional symbols, such as bus stop icons, terminals, and interchange points, were added to further enhance map readability. The styling was consistent across all maps to support comparative analysis and maintain visual coherence throughout the report.

- **Overlay Layers**

  To assess spatial equity and alignment with urban form, several thematic layers were overlaid onto the base transport network. These included land use zoning maps, population density heatmaps (from ward-level census data), and the locations of key public institutions such as hospitals, schools, and government offices. These overlays enabled the identification of mismatches between service provision and population or institutional demand. For example, areas with high population density but low transit coverage were marked as priority zones for future intervention. The inclusion of contextual urban data significantly enriched the understanding of each route's functional importance.

- **Heatmaps**

  Advanced GIS functions were used to generate heatmaps of both ridership intensity and service density. Ridership data collected from boarding and alighting surveys were aggregated spatially to highlight bus stops and segments with the highest passenger demand. These were represented using red-to-blue gradients, where red signified high load zones. Similarly, service density was mapped by calculating the number of overlapping routes per segment, offering a visual of potential redundancies or high coverage corridors. These heatmaps were instrumental in identifying overloaded segments, underserved areas, and transfer hotspots, directly feeding into the route performance evaluation and reclassification.

- **Application of Visualization Outputs**

  The visual outputs created through GIS were more than just illustrative—they played a central role in validating the analytical results from performance indicators, route classification, and network modeling. For instance, spatial clustering of core routes coincided with urban activity hubs, while feeder routes effectively extended reach to peripheral communities. During stakeholder meetings, these visual maps served as intuitive tools for explaining complex concepts, allowing policymakers and transit authorities to visually grasp route gaps, redundancies, or overlaps. This improved communication helped bridge the gap between technical findings and practical implementation.

2.8 Ethical Consideration and Limitation

In conducting this study on the classification of public transport routes in Kathmandu Valley, ethical integrity and transparency were maintained throughout all phases of data collection and analysis. Consideration was given to the rights, privacy, and consent of all participants and stakeholders. This section outlines the ethical protocols adopted, as well as the acknowledged limitations that may influence the interpretation and generalizability of the study findings.

- **Informed Consent**

  All individuals who participated in the study, including transportation experts interviewed for the AHP method and passengers or operators involved in field surveys, were fully briefed on the purpose, scope, and intended use of the research. Prior to participation, verbal informed consent was obtained in a respectful and culturally appropriate manner. Participants were assured that their involvement was voluntary and that they could opt out at any time without any negative consequences. This approach aligns with ethical research standards and ensures that the data collected reflected genuine input from informed individuals.

- **Privacy and Data Anonymization**

  To protect the privacy of all stakeholders, especially in the use of GPS tracking data and passenger boarding/alighting surveys, strict data handling protocols were followed. GPS routes were stripped of any identifiers linking them to individuals or specific vehicles. No personal identifiers—such as names, phone numbers, or digital IDs—were recorded during fieldwork. Data used for analysis were stored securely and were only accessible to authorized team members. Anonymization procedures ensured that spatial and ridership patterns could be analyzed without compromising individual privacy or safety, upholding ethical research standards, particularly in urban mobility studies.

- **Limitations of the Study**

  Despite the rigor applied in methodology design, some limitations are inherent to the study. Firstly, static demand assumptions were used due to the lack of temporal ridership data. This implies that variations in demand by time of day or day of the week were not fully captured. Secondly, fleet scheduling data—such as actual dispatch frequencies or vehicle assignments—were not consistently available across all routes, which may have introduced bias in estimating headways and operational efficiency.

Additionally, certain interdependencies among indicators (e.g., between stop density and travel time variability) were not mathematically decoupled, potentially affecting the independence assumption in multi-criteria decision-making (MCDM) models. These limitations are acknowledged to ensure transparency in the interpretation of the results.

This research methodology represents a comprehensive approach by integrating empirical field data, expert assessments, and advanced multi-criteria decision-making techniques to construct a hierarchical classification system for public transport routes. The study bridges theoretical models and practical insights, thereby offering a valuable tool for urban transport planners and policymakers. The resulting framework not only aids in understanding the current transit structure but also provides a scalable foundation for improving service equity, operational efficiency, and long-term mobility planning in Kathmandu Valley and beyond.

Chapter 3
DATA ANALYSIS AND FINDINGS

3.1 Descriptive Analysis of Indicators

The first step in the analysis involved computing descriptive statistics across the 22 selected routes. The key statistical measures were used to understand the central tendencies, dispersion, and range for each of the identified indicators. These indicators collectively offer insights into the service quality, efficiency, and spatial coverage of the existing transit system. Below is a detailed explanation of each indicator:

3.1.1 Route Length

It represents the total distance covered by a public transport route from its starting point to its terminal destination. This indicator provides a basic understanding of the spatial scale of services. In the dataset, route lengths ranged from short intra-ward connectors, often about 5 km, to long radial routes extending beyond 20 km, revealing a wide variety in service patterns and coverage strategies. The following chart shows the variation of route length across selected routes.

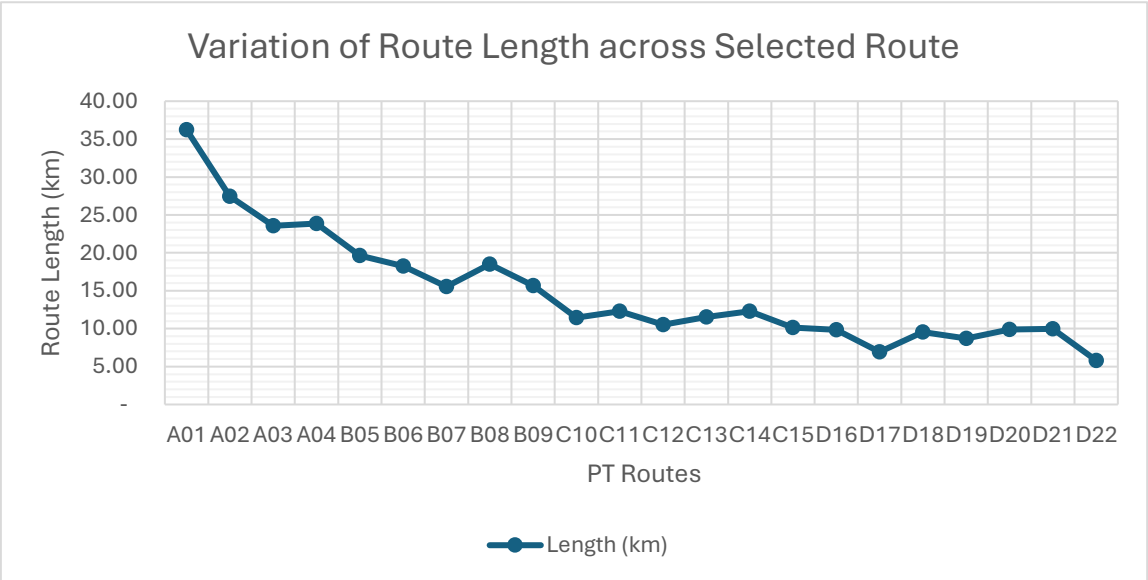


Figure 7: Line-Chart showing the Variation of Route length across selected routes

3.1.2 Stop Numbers

The Number of Stops on a route refers to the total count of boarding and alighting points. A higher number of stops typically enhances accessibility, allowing passengers to embark or disembark closer to their desired locations. However, it can also lead to longer travel times due to frequent halts, particularly in densely built-up areas. This trade-off between accessibility and travel speed is a critical aspect of transit planning.

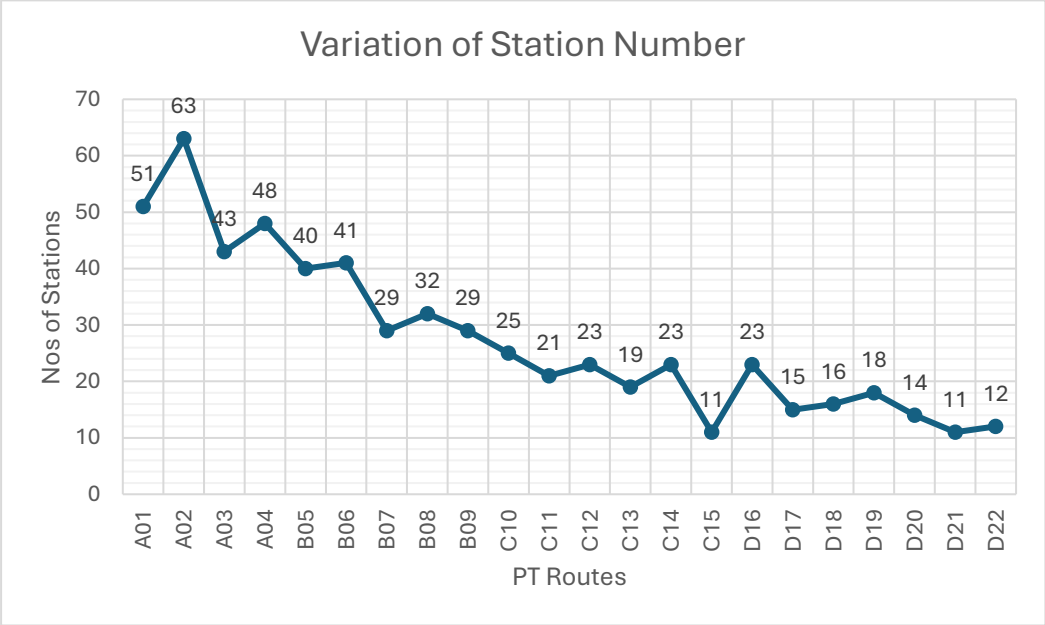


Figure 8: Line-Chart showing the Variation of Station Number across selected routes

3.1.3 Average Headway

The Average Headway measures the average time interval between two successive vehicles operating on the same route. It is a key indicator of service frequency. Lower headways indicate more frequent service and better user convenience, especially during peak hours, while higher headways suggest infrequent service, which may lead to longer waiting times and reduced ridership.

3.1.4 Daily Ridership

Daily Ridership reflects the total number of passengers utilizing a specific route within a 24-hour period. It serves as a direct proxy for travel demand and route popularity. High ridership figures often signify well-utilized routes, possibly connecting high-density areas

or serving major corridors, while lower values may point to underperforming routes or areas with low demand. The tree-map chart showing average ridership in both direction(Towards CBD and Away from CBD) of all 22 routes are shown below. The Ridership of Routes A01, A02, A03 and B05 towards CBD are comparatively higher than other routes.

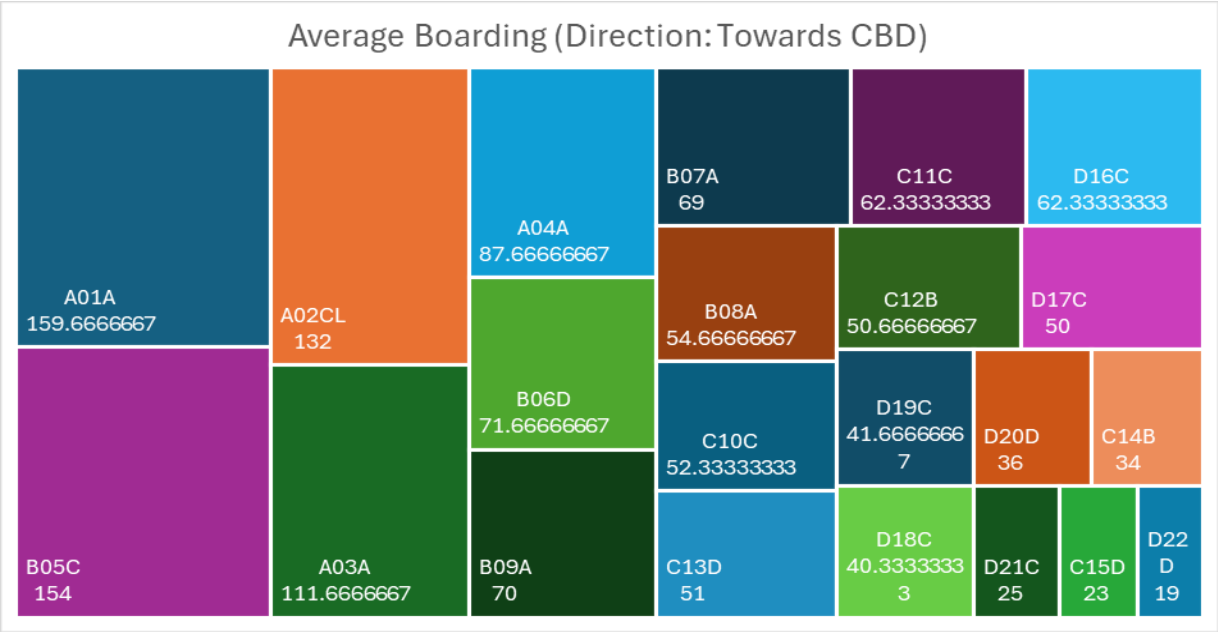


Figure 9: Average Ridership Heatmap (Towards CBD)

Similarly, the daily ridership of routes A01, A02, B05 and B06 away from CBD are comparatively higher than other routes.

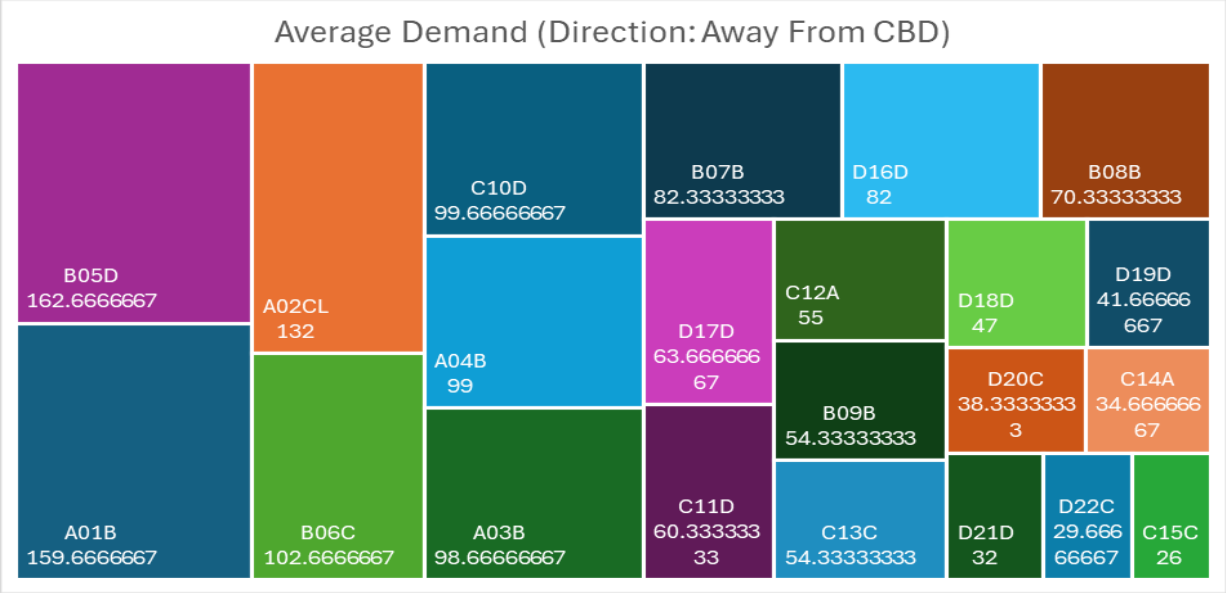


Figure 10: Average Ridership Heatmap (Away from CBD)

3.1.5 Vehicle Load Ratio

The Vehicle Load Ratio (VLR) is calculated as the ratio of the actual number of passengers to the vehicle's rated capacity. A VLR value greater than 1 indicates that vehicles are operating above their capacity, leading to overcrowding, passenger discomfort, and potential safety concerns. On the other hand, very low values suggest underutilization, which may reflect inefficiencies in service allocation. Out of 22 routes, most of the routes have VLR above 1, which hampers the service quality of the PT due to overcrowding, and discomfort.

Towards CBD, only 5 routes have VLR less than 1. Out of 22 routes, B05 (Tikathali-Balkumari-Koteshwor-Putalisadak-Baluwatar-Kapan-Phaikaa) has highest VLR ratio (i.e 2.0), followed by route D16, B07, A01 and so on.

Whereas On direction away from CBD, only three routes (A03, D18 and A02) have VLR ratio less than 1. The maximum VLR in this direction is 2.27 in route D17 (Raniban-Dhungedhara-Balaju-Lainchaur-NAC), 2.23 in route C10 (Tinpiple-Machhapokhari-Balaju-Lainchaur-NAC) and 2.04 in route B06 (Balkot-Koteshwor-New Baneshwor-Tripureshwor-Kalanki-Swoyambhu).

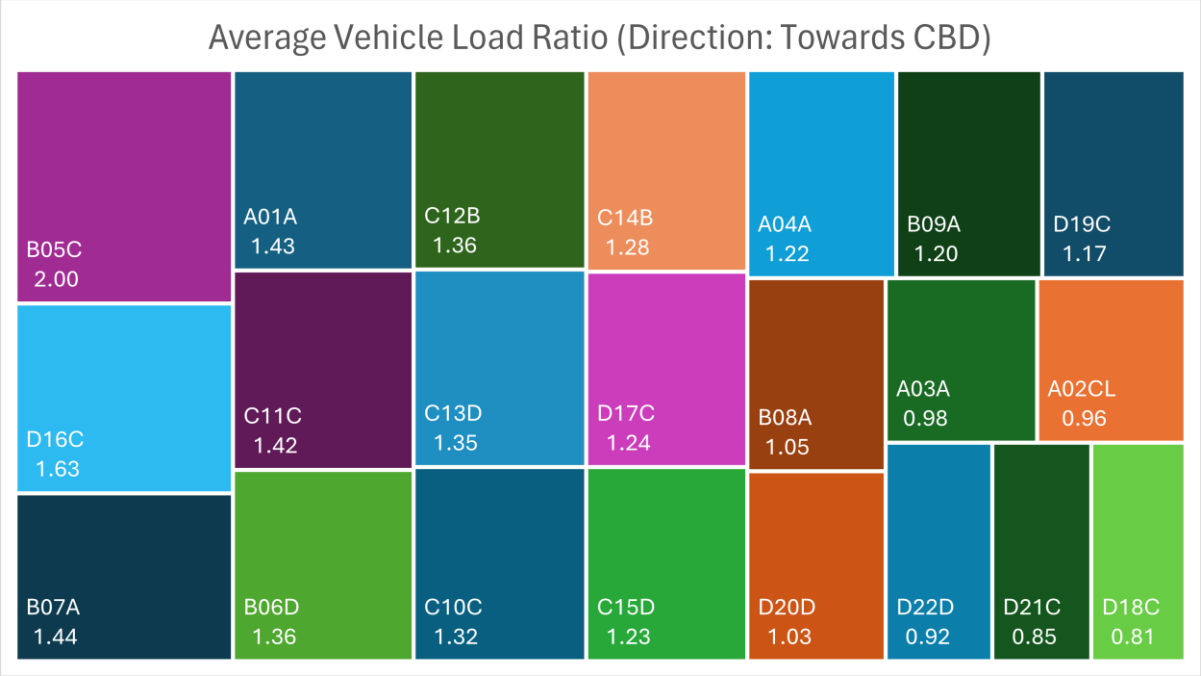


Figure 11: Average Vehicle Load Ratio Heatmap (Towards CBD)

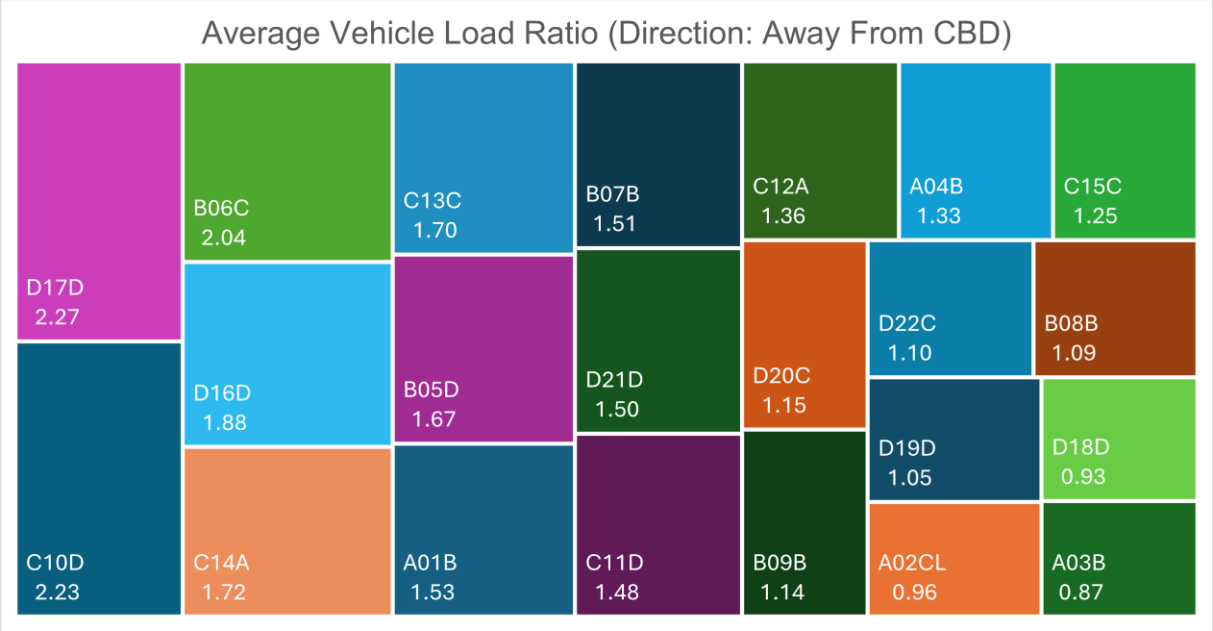


Figure 12: Average Vehicle Load Ratio Heatmap (Away from CBD)

3.1.6 Demand-Capacity Ratio (DCR)

The Demand-Capacity Ratio (DCR) is a key operational indicator that measures the balance between passenger demand and the available carrying capacity on a given public transport route. It is calculated as the ratio of average passenger demand to the average seating (or total) capacity of vehicles operating on that route. A DCR value close to or slightly below 1 indicates efficient utilization of vehicle capacity, where supply closely matches demand. Conversely, a DCR significantly greater than 1 suggests overcrowding and insufficient supply, potentially leading to discomfort, safety concerns, and reduced service attractiveness. On the other hand, a low DCR (much below 1) may point to underutilized services, indicating excess capacity and possible inefficiencies in resource allocation. By analyzing DCR across multiple routes, planners can identify segments where additional vehicles or frequency adjustments may be needed, or where resources could be reallocated to improve overall service efficiency. Thus, the Demand-Capacity Ratio serves as a vital metric for optimizing both operational effectiveness and user satisfaction in public transport networks.

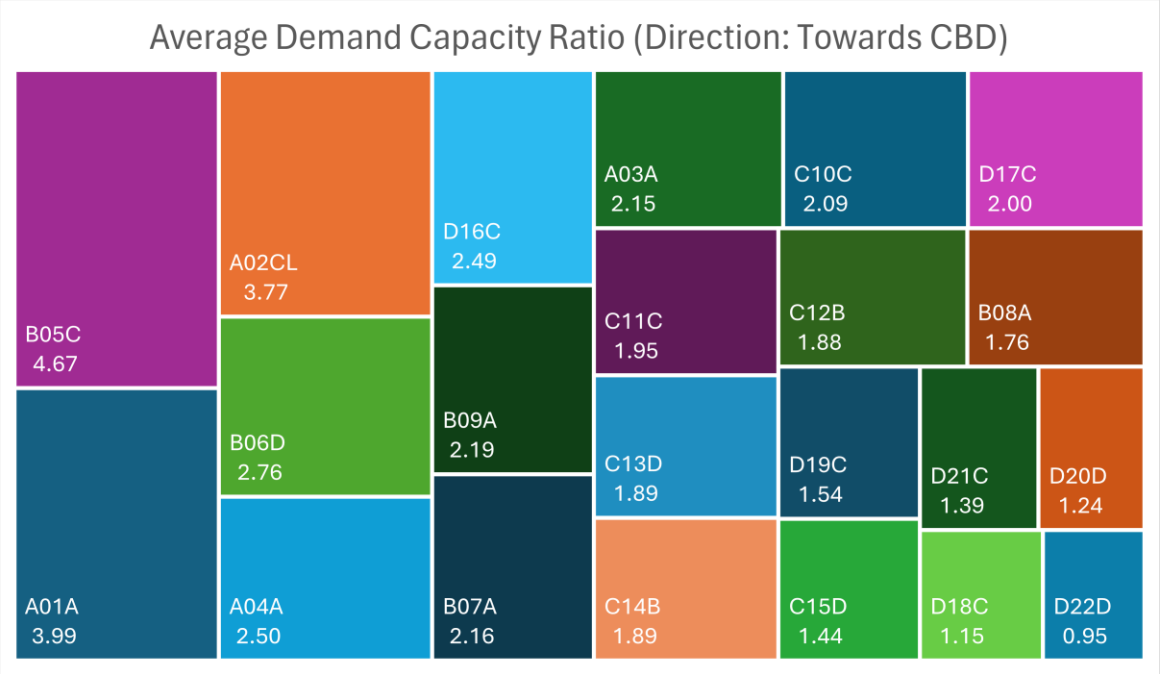


Figure 13: Average Demand Capacity Ratio Heatmap (Towards CBD)

The DCR value is very high in almost all of the routes. Only one route, D22 (Lagankhel-Jawalakhel-Maitighar-Ratnapark) in direction towards CBD has DCR value less than 1. Routes B05, A01 and A02 have DCR value greater than 3. Whereas in direction, Away from CBD, none of the routes have DCR value less than 1. In this direction the DCR value is as high as 4.93 in route B05, followed by 3.99 in route A01 and C10. The tree-map chart of DCR value of all routes are shown in figures.

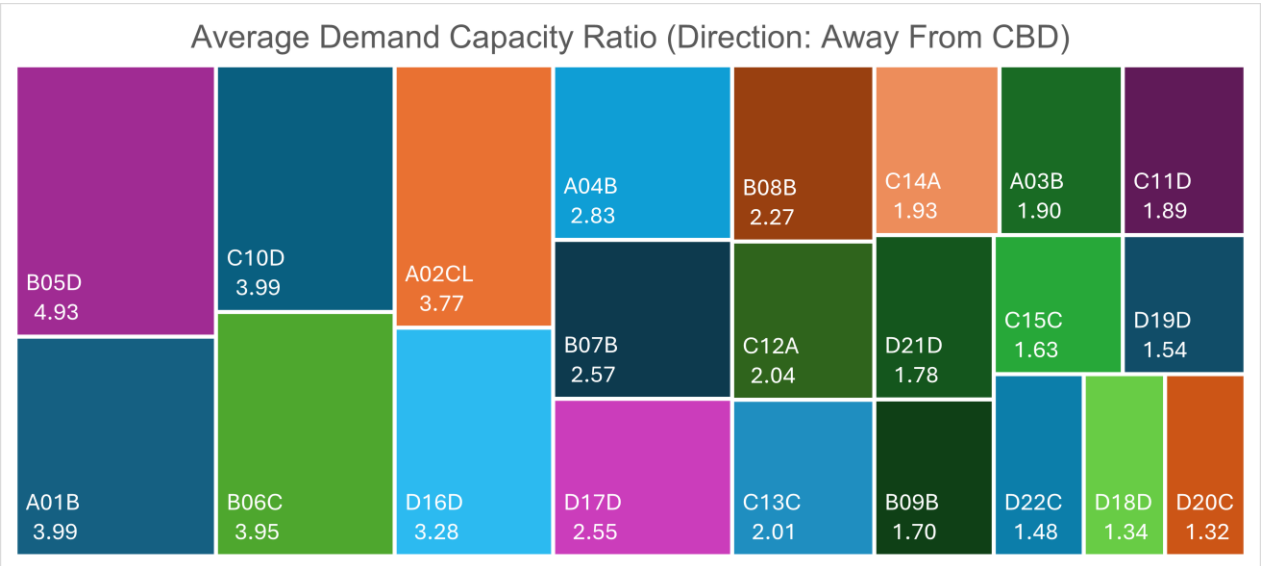


Figure 14: Average Demand Capacity Ratio Heatmap (Away from CBD)

3.1.7 Operational Hours

Operational Hours indicate the duration of service availability in a day, measured from the first trip to the last. Longer operational hours contribute to enhanced accessibility for passengers traveling during early morning or late evening hours. Limited operational hours can restrict mobility for shift workers, students, and other off-peak users. Almost all routes operates from 5am in the morning till 8pm in the evening in KV.

3.1.8 Stop Density

The Stop Density measures the number of bus stops per kilometer of route length. Higher stop densities are typically associated with central business districts or urban cores, providing dense accessibility. In contrast, lower stop densities are characteristic of express routes or services in suburban and peripheral regions aiming to maintain faster travel speeds. The following map shows the location of stops and their distance.

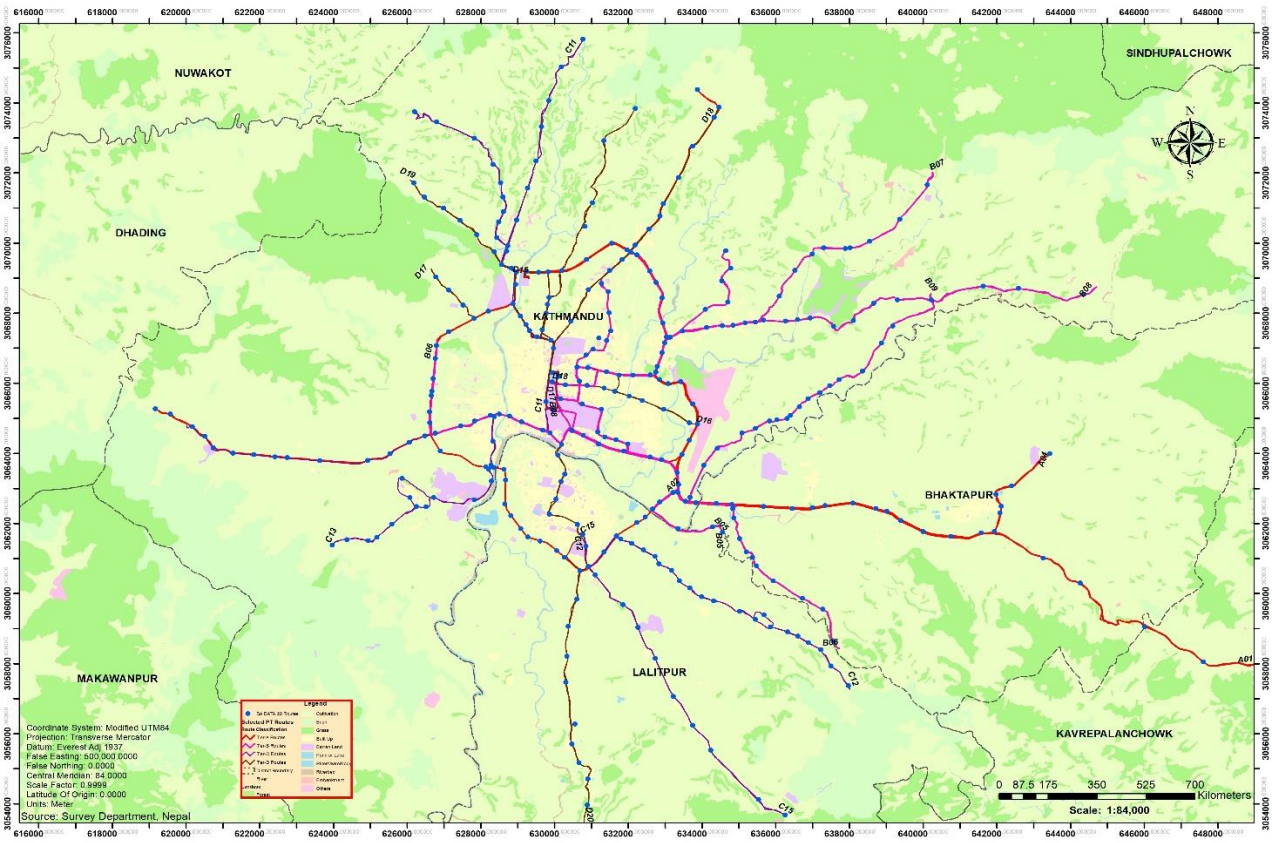


Figure 15: Spatial Distribution of Stops along the selected routes

3.1.9 Route Overlap Score

The Route Overlap Score represents the extent to which a route shares its path with other routes in the network. A high overlap ratio suggests significant redundancy, which may result in inefficient use of resources or route congestion. Conversely, a low overlap ratio indicates unique routing, potentially contributing to better spatial coverage and reducing competition among services. Critical sections where the selected route overlaps are shown in below. The thicker lines shows more routes are overlapped in that section.

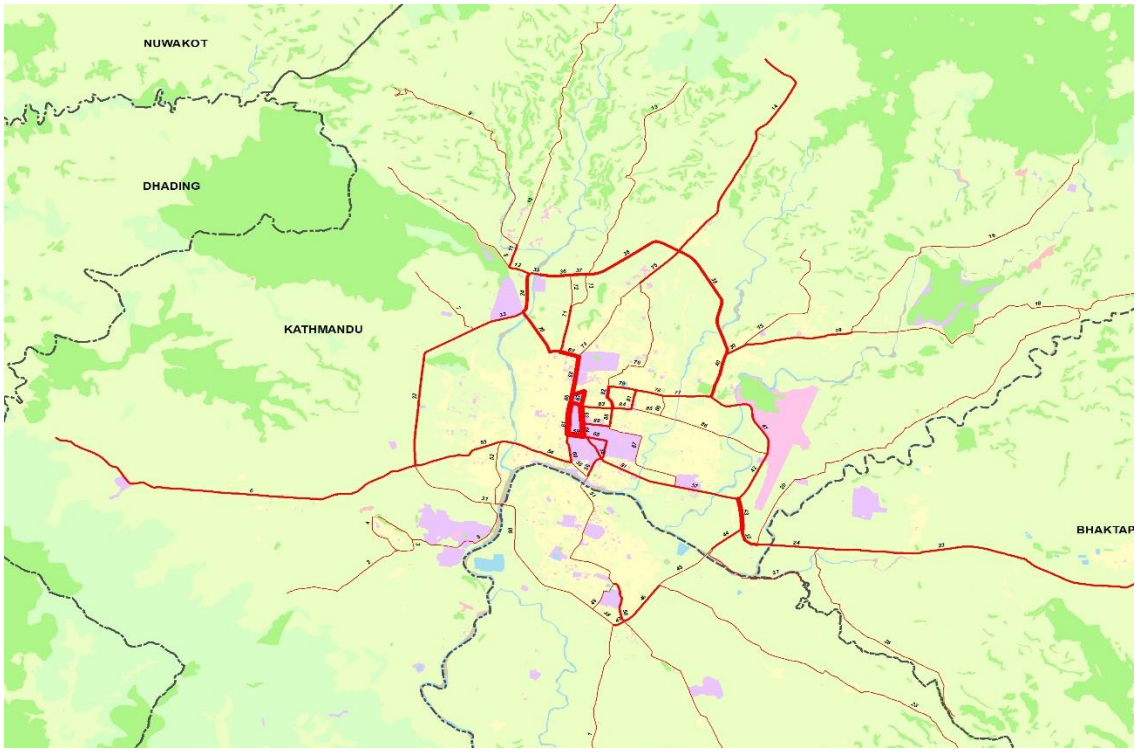


Figure 16: Spatial Distribution of Critical sections along the selected routes

3.1.10 Travel Time Variability

Travel Time Variability assesses the inconsistency in travel times on the same route over multiple trips or days. High variability indicates poor reliability and may be due to unpredictable traffic conditions, signal delays, or inconsistent driver behavior. Such variability adversely affects passengers' ability to plan trips and reduces the perceived reliability of public transport. Tier-A Routes have comparatively higher travel time than other tier routes. This shows that travel time is directly proportional to the route length.

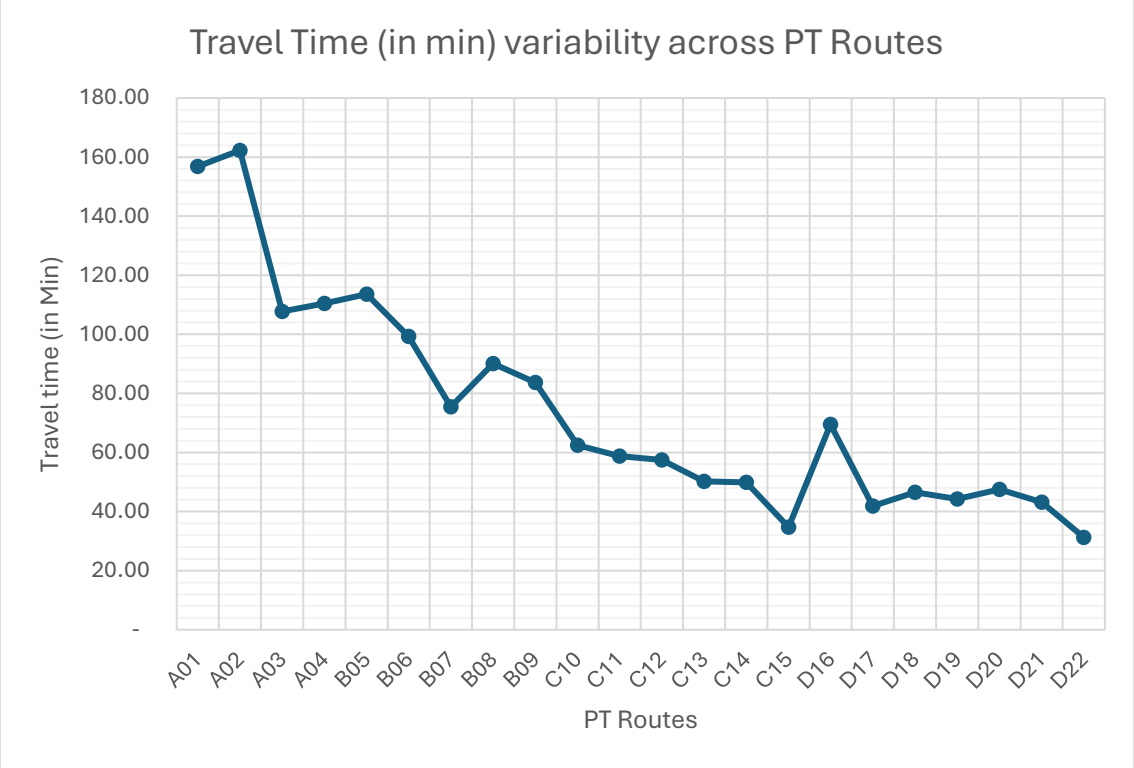


Figure 17: Line-Chart showing the Variation of Travel time across the selected routes

3.1.11 Connectivity Index

Connectivity Index measures how well a particular route integrates with the broader transport network. This includes connections to other bus routes or modes such as microbuses, tempos, or even non-motorized modes. A higher index value suggests better intermodal integration and ease of transfers, which is essential for creating a seamless and user-friendly transit system.

Comparatively, These indicators provide a multi-dimensional view of the performance and characteristics of the selected routes. Understanding the variation and distribution of these metrics is crucial for identifying strengths, weaknesses, and opportunities for optimizing the public transport network.

3.2 Descriptive Analysis of Tier-wise Routes

The descriptive analysis conducted across the four tiers (22 selected public transport routes) serves as a critical preliminary step in understanding their baseline performance before applying more advanced ranking, clustering, or optimization models. This stage of analysis focuses on evaluating a range of key operational indicators such as route length, number of stops, average headway, ridership levels, vehicle load ratios, and other relevant metrics. By assessing these indicators on a route-by-route basis, the study generates a comparative performance profile for each route. This comparison allows for the identification of routes that consistently perform well across several dimensions—such as those with optimal frequency, efficient stop spacing, or high ridership relative to capacity—and those that may be underperforming due to issues like overcrowding, long headways, or excessive overlap with other routes.

The descriptive analysis also helps in uncovering patterns within the dataset, such as whether longer routes tend to have higher travel time variability, or whether routes with high stop density are primarily located in central zones. Additionally, the method helps to highlight outliers – routes that deviate significantly from the norm – either in a positive or negative direction. For instance, a route with extremely high ridership but low operational hours may suggest untapped potential for service expansion.

Another key output of the analysis is benchmarking, which involves calculating the average value for each indicator across all tier of routes. These averages serve as reference points for evaluating individual route performance. Routes with metrics significantly above or below the average can be flagged for further investigation. For example, a route with a demand-capacity ratio much higher than the average may be facing overcrowding and could benefit from capacity enhancements.

Overall, this descriptive analysis not only provides a foundation for evidence-based planning and decision-making but also informs the design of later analytical stages such as route prioritization, service optimization, or policy interventions.

3.2.1 Tier A – Long Routes (> 20 km)

Long routes represent primary trunk or regional connections that span across multiple urban and peri-urban zones. These routes serve the highest number of passengers over the longest distances, often connecting city centers to distant municipalities or emerging growth areas. Due to their extended length, they face the highest exposure to traffic congestion and operational unpredictability. The attributes of tier-A routes are shown in table below:

Table 7: Attributes of Tier-A Public Transportation Routes

Route Code	Route Name	Average Demand	Avg Seat Capacity	Avg Travel Time	Avg Length	Avg Speed	Avg VLR	Avg DCR	Avg Max Pax
A01A	Naya Buspark-Maharajgunj-Koteshwor-Banepa-Dhulikhel	159.67	40	156.78	36.23	13.87	1.43	3.99	57
A01B	Naya Buspark-Maharajgunj-Koteshwor-Banepa-Dhulikhel	159.67	40	156.83	36.31	13.89	1.53	3.99	61
A02CL	Ringroad Circulation	132.00	35	162.27	27.44	10.15	0.96	3.77	34
A03A	Thankot-Kalanki-Naya Buspark-Maharajgunj-Budhanilkantha	111.67	52	111.47	23.64	12.72	0.98	2.15	51
A03B	Thankot-Kalanki-Naya Buspark-Maharajgunj-Budhanilkantha	98.67	52	104.01	23.48	13.55	0.87	1.90	45
A04A	Bansbari (Bhaktapur)-Suryabinayak-Koteshwor-Chabahil -Naya Buspark	87.67	35	109.09	23.88	13.13	1.22	2.50	43
A04B	Bansbari (Bhaktapur)-Suryabinayak-Koteshwor-Chabahil -Naya Buspark	99.00	35	111.88	23.86	12.80	1.33	2.83	47

The distribution of average demand and travel time across both direction of Tier-A routes are highlighted in graph below:

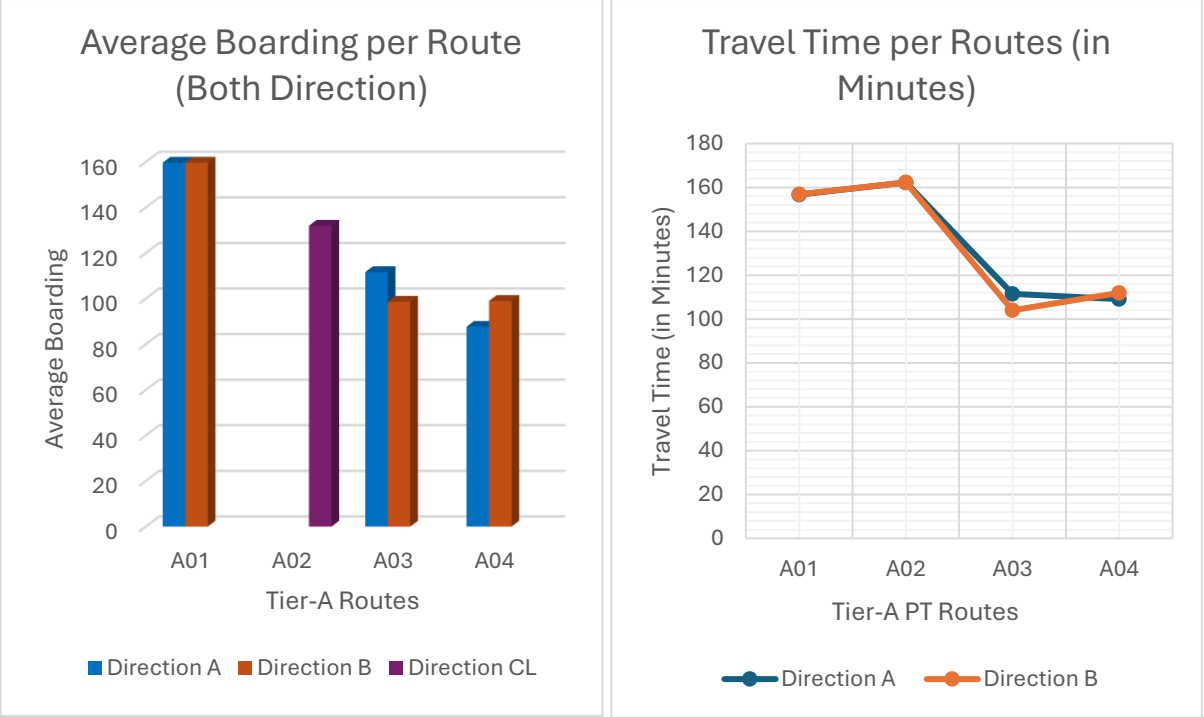


Figure 18: Bar Chart showing the Average Demand and Travel Time of Tier-A PT Routes

Similarly, the comparison between maximum passengers in vehicle during the trip and the actual seat capacity can be visualized through following graph. It can be concluded that all routes of tier-A carry more passengers than their seat capacity in both direction.

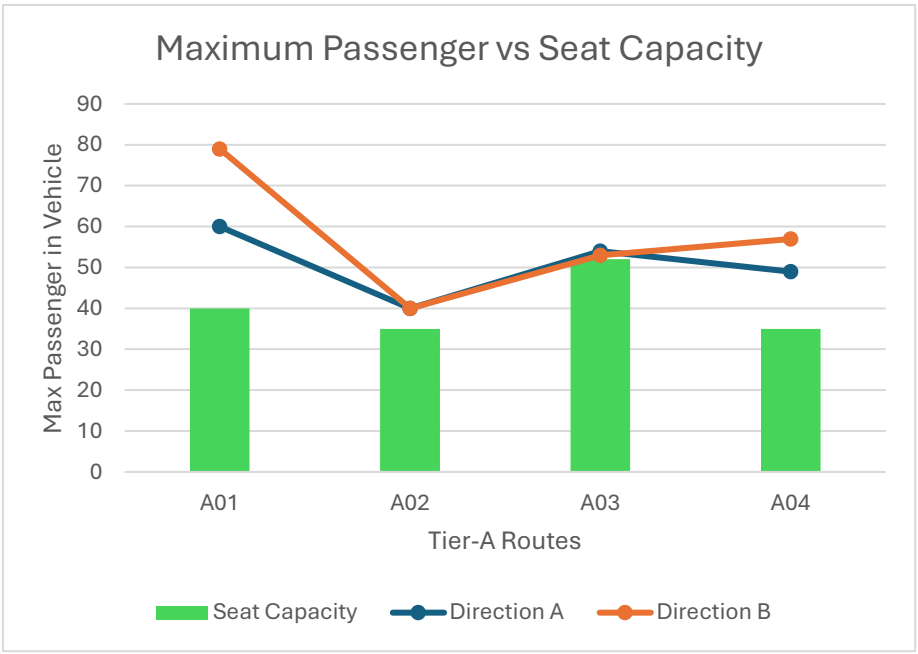


Figure 19: Chart showing the distribution of Maximum pax & seat capacity of Tier-A Routes

Similarly, The heatmap showing the variation of vehicle load ratio and demand capacity ratio are shown below:

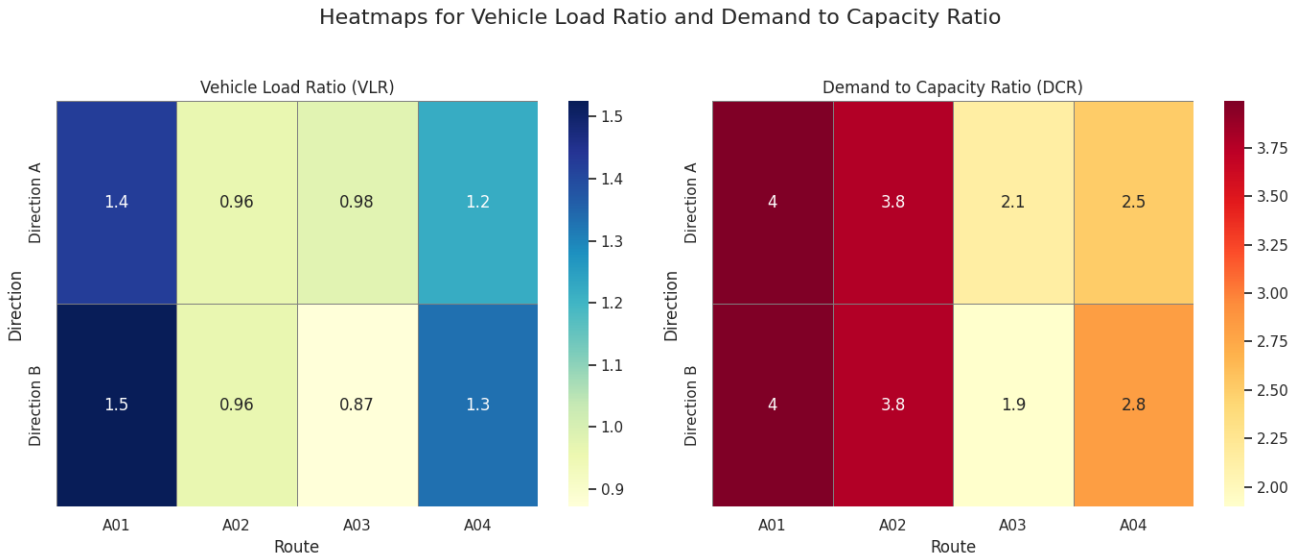


Figure 20: Heatmaps of VLR and DCR of Tier-A PT Routes

3.2.2 Tier B – Medium-Long Routes (15 km-20 km)

These medium-long routes are high-capacity corridors that witness substantial passenger demand during peak hours. They often function as backbones of the city's transit network, supporting both direct travel and transfer-based journeys. Due to their longer lengths, they require careful attention to travel time variability, schedule adherence, and fleet utilization. Investments in intelligent transportation systems (ITS), signal priority, or partial lane segregation may be necessary to maintain efficiency and reliability along these corridors. The attributes of Tier-B routes are shown in table below:

Table 8: Attributes of Tier-B Public Transportation Routes

Route Code	Route Name	Average Demand	Avg Seat Capacity	Avg Travel Time (min)	Avg Length	Avg Speed (kmph	Avg VLR	Avg DCR	Avg Max Pax Onbrd
B05C	Tikathali-Balkumari-Koteshwor-Putalisadak-Baluwatar-Kapan-Phaikaa	154.00	33	112.76	19.77	10.52	2.00	4.67	66
B05D	Tikathali-Balkumari-Koteshwor-Putalisadak-Baluwatar-Kapan-Phaikaa	162.67	33	114.34	19.56	10.26	1.67	4.93	55
B06D	Balkot-Koteshwor-New Baneshwor-Tripureshwor-Kalanki-Swoyambhu	71.67	26	98.84	18.12	11.00	1.36	2.76	35
B06C	Balkot-Koteshwor-New Baneshwor-Tripureshwor-Kalanki-Swoyambhu	102.67	26	99.81	18.36	11.04	2.04	3.95	53
B07A	Sundarijal-Chabahil-Gausala-Dillibazar-Bagbazar-NAC	69.00	32	87.46	14.95	10.26	1.44	2.16	46
B07B	Sundarijal-Chabahil-Gausala-Dillibazar-Bagbazar-NAC	82.33	32	63.38	16.14	15.28	1.51	2.57	48
B08A	Sankhu-Chabahil-Gausala-Dillibazar-Bagbazar-NAC	54.67	31	85.06	18.09	12.76	1.05	1.76	33
B08B	Sankhu-Chabahil-Gausala-Dillibazar-Bagbazar-NAC	70.33	31	95.01	18.93	11.96	1.09	2.27	34
B09A	Mulpani-Pepsicola-Koteshwor-New Baneshwor-NAC	70.00	32	83.02	15.40	11.13	1.20	2.19	38
B09B	Mulpani-Pepsicola-Koteshwor-New Baneshwor-NAC	54.33	32	84.37	15.91	11.32	1.14	1.70	36

The distribution of average demand, maximum passenger vs seat capacity and the travel time across both direction of Tier-B routes are highlighted in graph below:

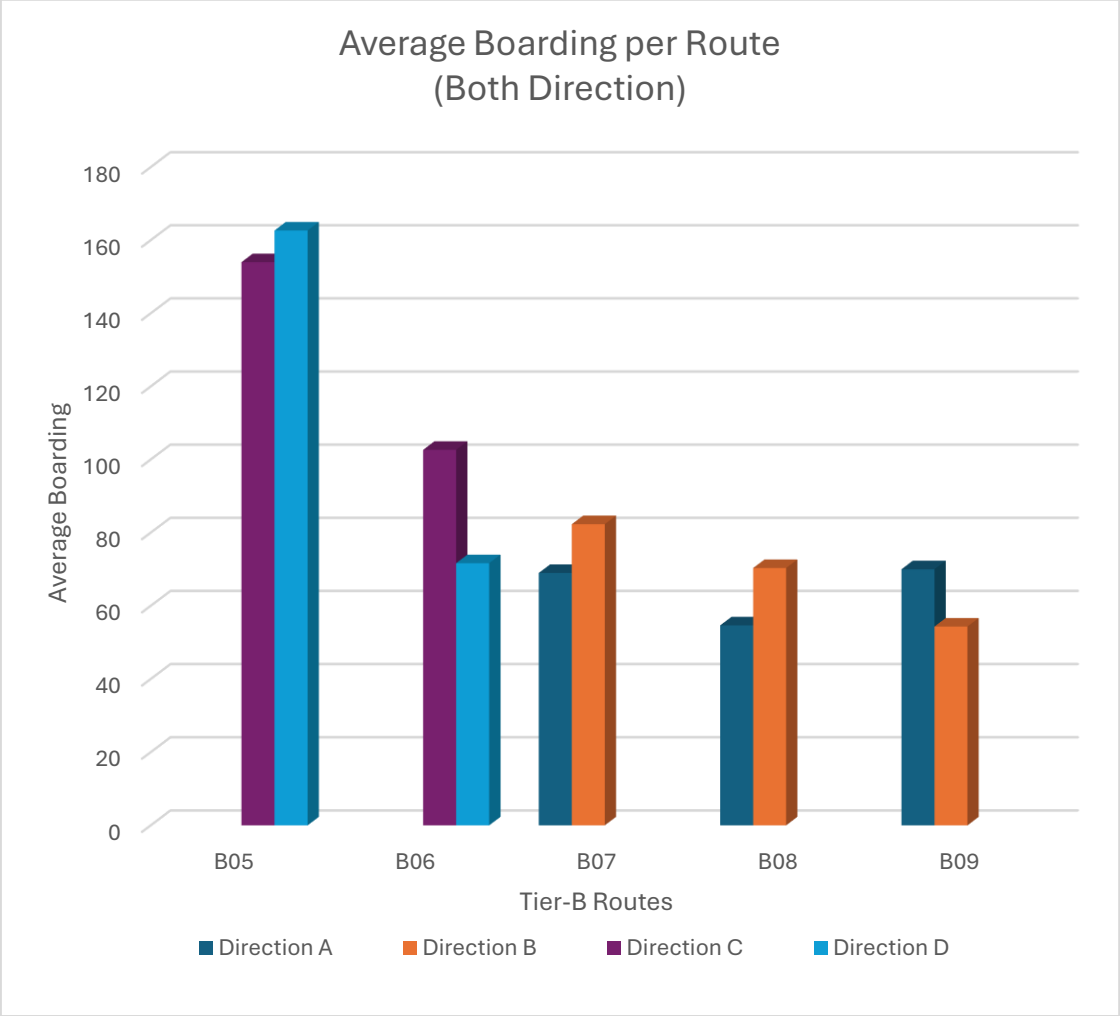


Figure 21: Bar-Chart showing the Average Demand of Tier-B PT Routes

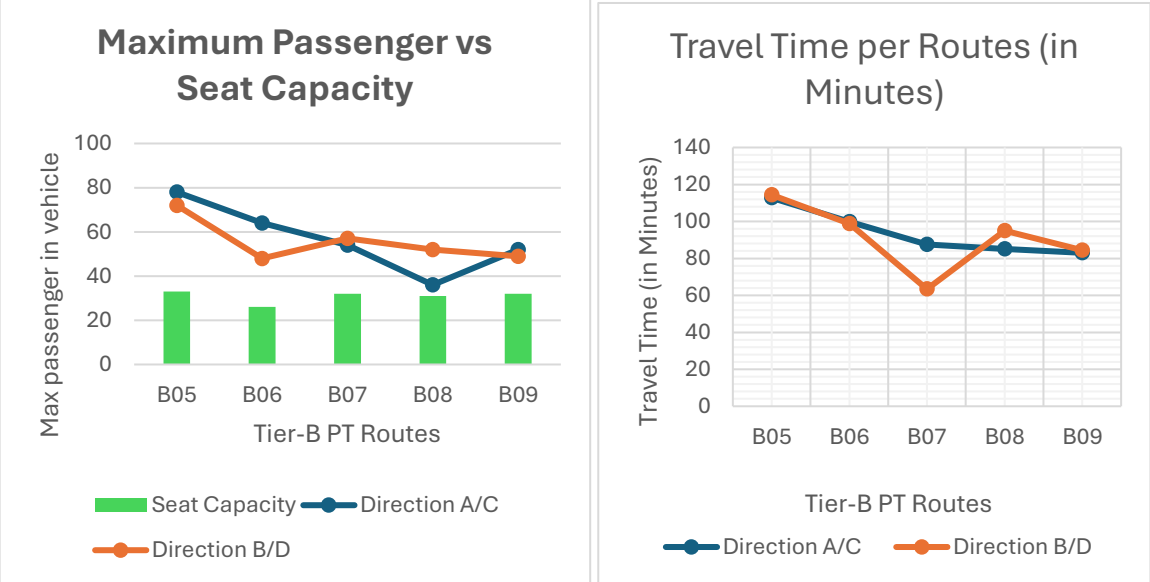


Figure 22: Chart showing distribution of Max pax vs seat Capacity & travel times of Tier-B Routes

Similarly, The heatmap showing the variation of vehicle load ratio and demand capacity ratio are shown below:

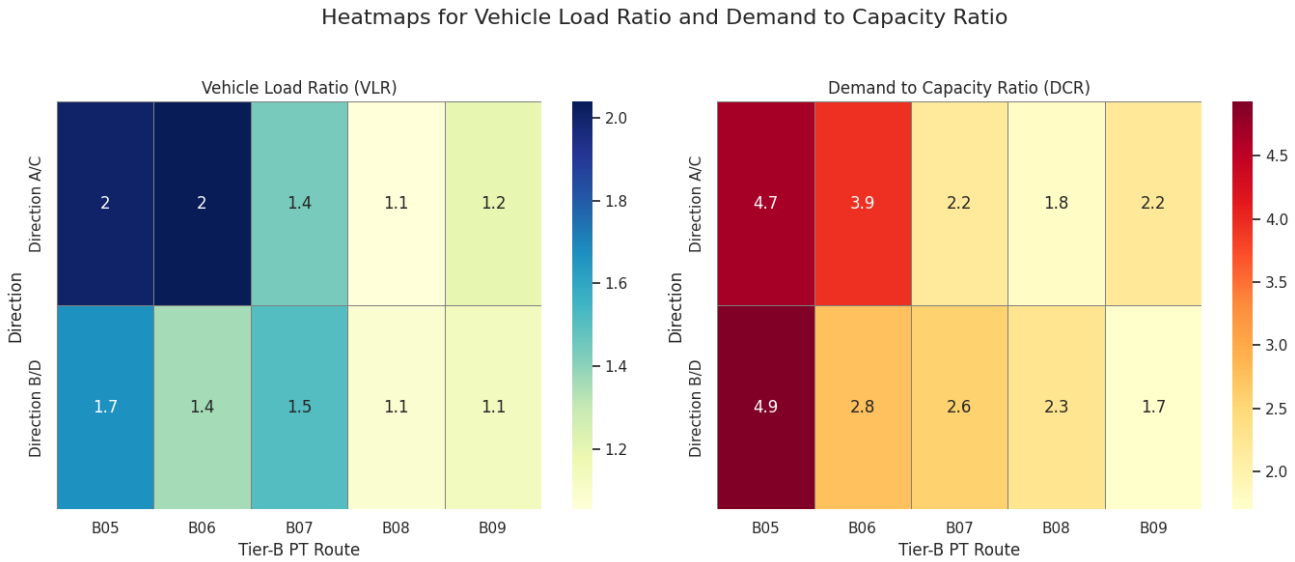


Figure 23: Heatmaps of VLR and DCR of Tier-B PT Routes

3.2.3 Tier C– Medium-Short Routes (10 km-15 km)

Medium-short routes strike a balance between accessibility and operational reach. These routes usually connect multiple neighborhoods or extend slightly beyond local boundaries. They are critical in linking secondary activity centers, educational institutions, or industrial zones with residential areas. Medium-short routes offer moderate trip durations and frequencies, allowing for a cost-effective service model. The attributes of Tier-B routes are shown in table below:

Table 9: Attributes of Tier-C Public Transportation Routes

Route Code	Route Name	Average Demand	Avg Seat Capacity	Avg Travel Time (min)	Avg Length	Avg Speed (kmph	Avg VLR	Avg DCR	Avg Max Pax Onboard
C10C	Tinpiple-Machhapokhari-Balaju-Lainchaur-NAC	52.33	25	50.71	11.60	13.73	1.32	2.09	33
C10D	Tinpiple-Machhapokhari-Balaju-Lainchaur-NAC	99.67	25	74.11	11.28	9.13	2.23	3.99	56
C11C	Jhor-Nepaltar-Machhapokhari-Lainchaur-NAC	62.33	32	59.58	12.97	13.06	1.42	1.95	45
C11D	Jhor-Nepaltar-Machhapokhari-Lainchaur-NAC	60.33	32	57.89	11.74	12.16	1.48	1.89	47
C12B	Lagankhel-Gwarko-Sanagaun-Lubhu-Dhungin	50.67	27	54.76	10.38	11.37	1.36	1.88	37
C12A	Lagankhel-Gwarko-Sanagaun-Lubhu-Dhungin	55.00	27	60.06	10.71	10.70	1.36	2.04	37
C13D	Puspalal Buspark-Kirtipur-Balkhu-Kalimati-NAC	51.00	27	46.99	11.34	14.47	1.35	1.89	36
C13C	Puspalal Buspark-Kirtipur-Balkhu-Kalimati-NAC	54.33	27	53.47	11.77	13.20	1.70	2.01	46
C14B	Thankot-Kalanki-Kalimati-NAC	34.00	18	44.26	11.40	15.46	1.28	1.89	23
C14A	Thankot-Kalanki-Kalimati-NAC	34.67	18	55.45	13.22	14.30	1.72	1.93	31
C15D	Lagankhel-Satdobato-Harisiddhi-Godawari	23.00	16	37.87	10.33	16.37	1.23	1.44	20
C15C	Lagankhel-Satdobato-Harisiddhi-Godawari	26.00	16	31.62	9.98	18.93	1.25	1.63	20

The distribution of average demand and travel time across both direction of Tier-A routes are highlighted in graph below:

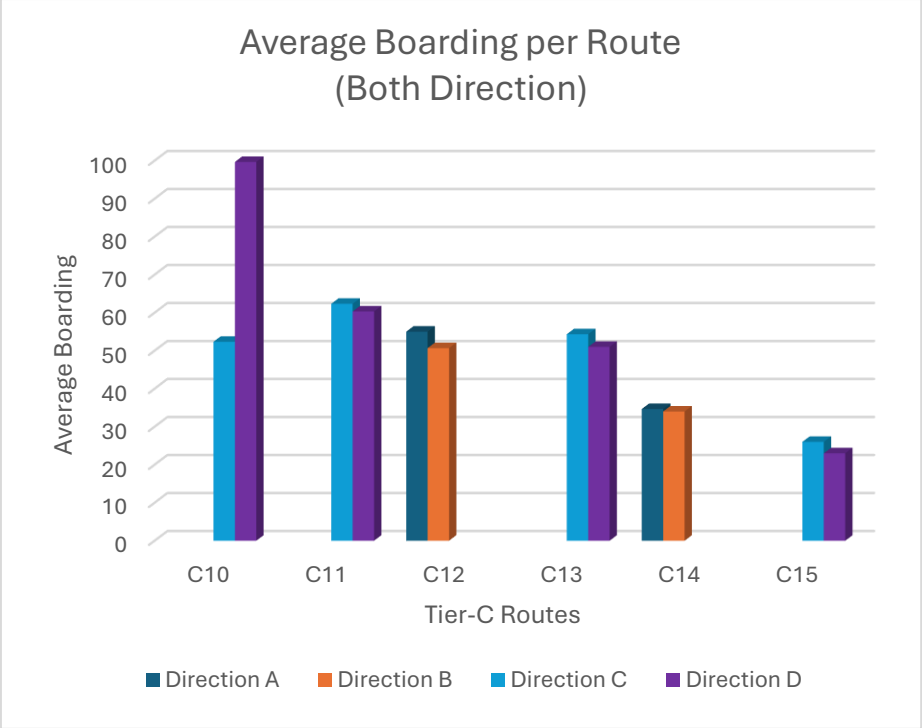


Figure 24: Bar-Chart showing the Average Demand of Tier-C PT Routes

Similarly, the comparison between maximum passengers in vehicle during the trip and the actual seat capacity can be visualized through following graph. It can be concluded that all routes of tier-C carry more passengers than their seat capacity in both direction.

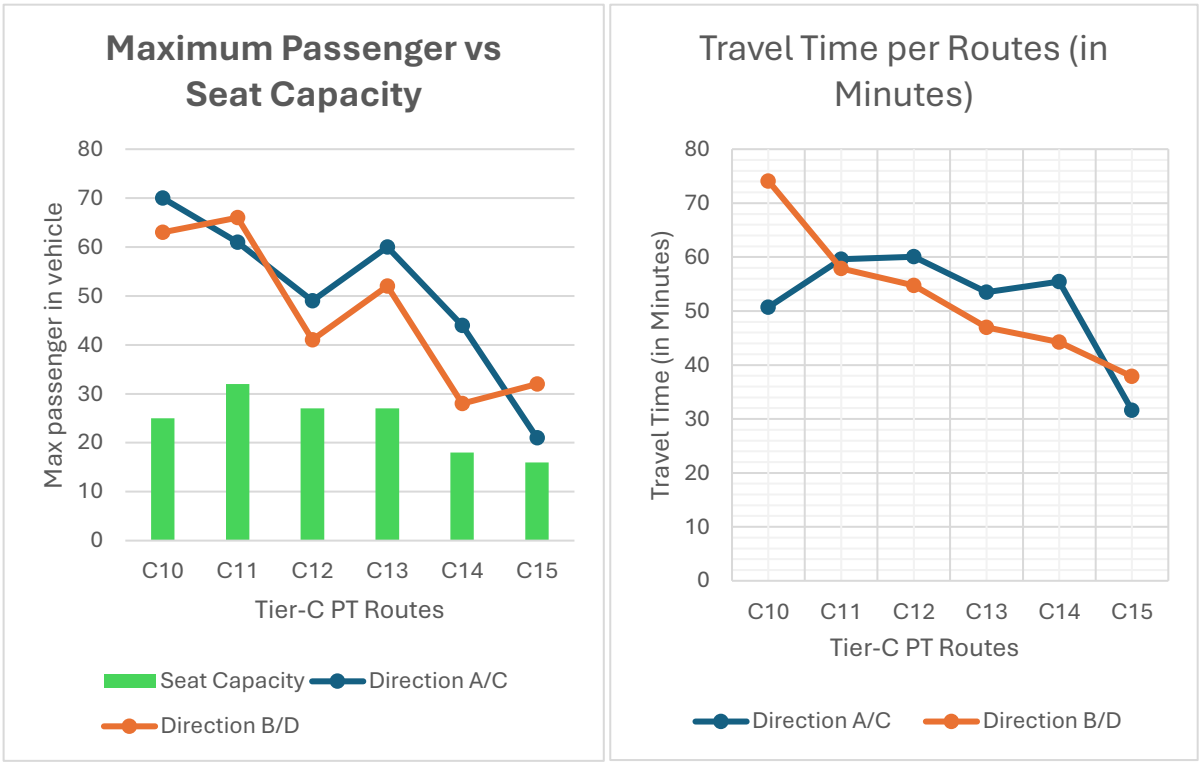


Figure 25: Chart showing distribution of Max pax vs seat Capacity & travel times of Tier-B Routes

Similarly, The heatmap showing the variation of VLR and DCR are shown as:

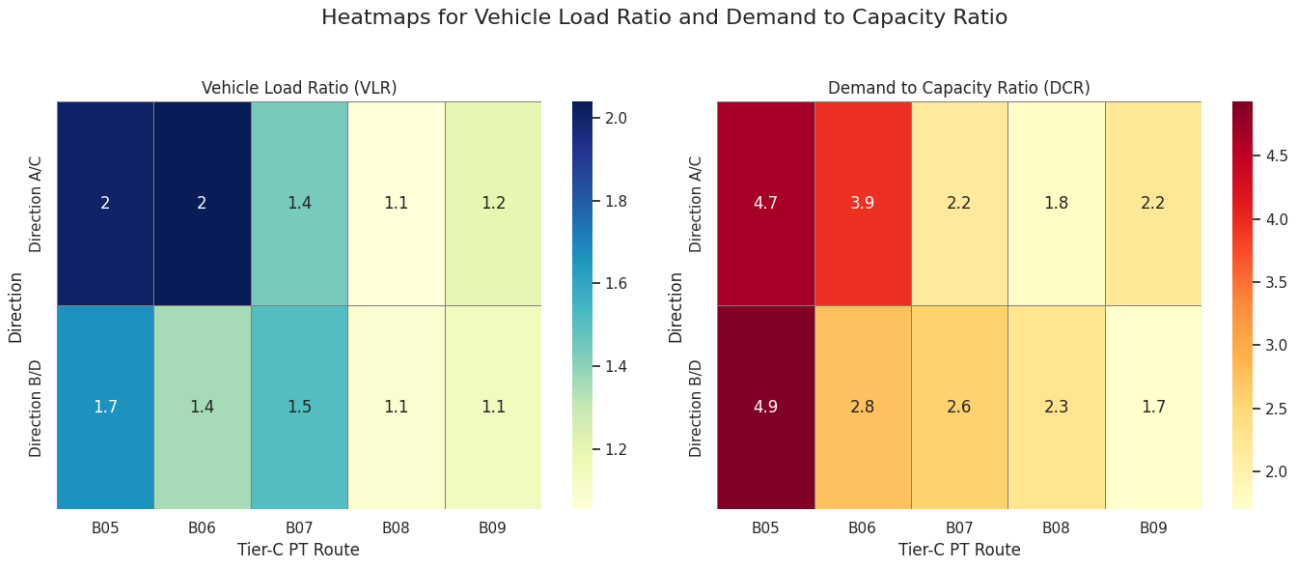


Figure 26: Heatmaps of VLR and DCR of Tier-C PT Routes

3.2.4 Tier D – Short Routes (≤ 10 km)

Routes within this category are relatively short and primarily serve as feeder or local circulator services. Due to their compact nature, they are characterized by higher stop densities, shorter trip durations, and often operate with smaller vehicle fleets. These routes enhance last-mile connectivity and are essential in providing accessibility in densely populated urban areas.. The attributes of Tier-B routes are shown as

Table 10: Attributes of Tier-C Public Transportation Routes

Route Code	Route Name	Average Demand	Avg Seat Capacity	Avg Travel Time (min)	Avg Length	Avg Speed (kmph	Avg VLR	Avg DCR	Avg Max Pax
D16C	Naya Buspark-Gongabu-Putalisadak-Purano Baneshwor-Sinamangal	62.33	25	59.20	9.87	10.01	1.63	2.49	41
D16D	Naya Buspark-Gongabu-Putalisadak-Purano Baneshwor-Sinamangal	82.00	25	79.72	9.83	7.40	1.88	3.28	47

Route Code	Route Name	Average Demand	Avg Seat Capacity	Avg Travel Time (min)	Avg Length	Avg Speed (kmph	Avg VLR	Avg DCR	Avg Max Pax
D17C	Raniban-Dhungedhara-Balaju-Lainchaur-NAC	50.00	25	40.31	7.47	11.13	1.24	2.00	31
D17D	Raniban-Dhungedhara-Balaju-Lainchaur-NAC	63.67	25	43.43	6.41	8.85	2.27	2.55	57
D18C	Budhanilkantha-Maharajgunj-Lazimpat-Ratnapark	40.33	35	44.21	9.75	13.23	0.81	1.15	28
D18D	Budhanilkantha-Maharajgunj-Lazimpat-Ratnapark	47.00	35	48.79	9.36	11.51	0.93	1.34	33
D19C	Goldhunga-Machhapokhari-Balaju-Lainchaur-NAC	41.67	27	39.89	9.09	13.67	1.17	1.54	32
D19D	Goldhunga-Machhapokhari-Balaju-Lainchaur-NAC	41.67	27	48.69	8.33	10.26	1.05	1.54	28
D20D	Lagankhel-Satdobato-Thecho-Chapagaun-Takhel Chautara	36.00	29	48.12	10.02	12.49	1.03	1.24	30
D20C	Lagankhel-Satdobato-Thecho-Chapagaun-Takhel Chautara	38.33	29	46.81	9.78	12.54	1.15	1.32	33
D21C	Chandeshwori-Tokha-Samakhusi-Lainchaur-NAC	25.00	18	40.28	10.73	15.98	0.85	1.39	15
D21D	Chandeshwori-Tokha-Samakhusi-Lainchaur-NAC	32.00	18	45.97	9.99	13.04	1.50	1.78	27
D22D	Lagankhel-Jawalakhel-Maitighar-Ratnapark	19.00	20	30.31	5.90	11.68	0.92	0.95	18
D22C	Lagankhel-Jawalakhel-Maitighar-Ratnapark	29.67	20	32.24	5.72	10.65	1.10	1.48	22

The distribution of average demand and travel time across both direction of Tier-A routes are highlighted in graph below:

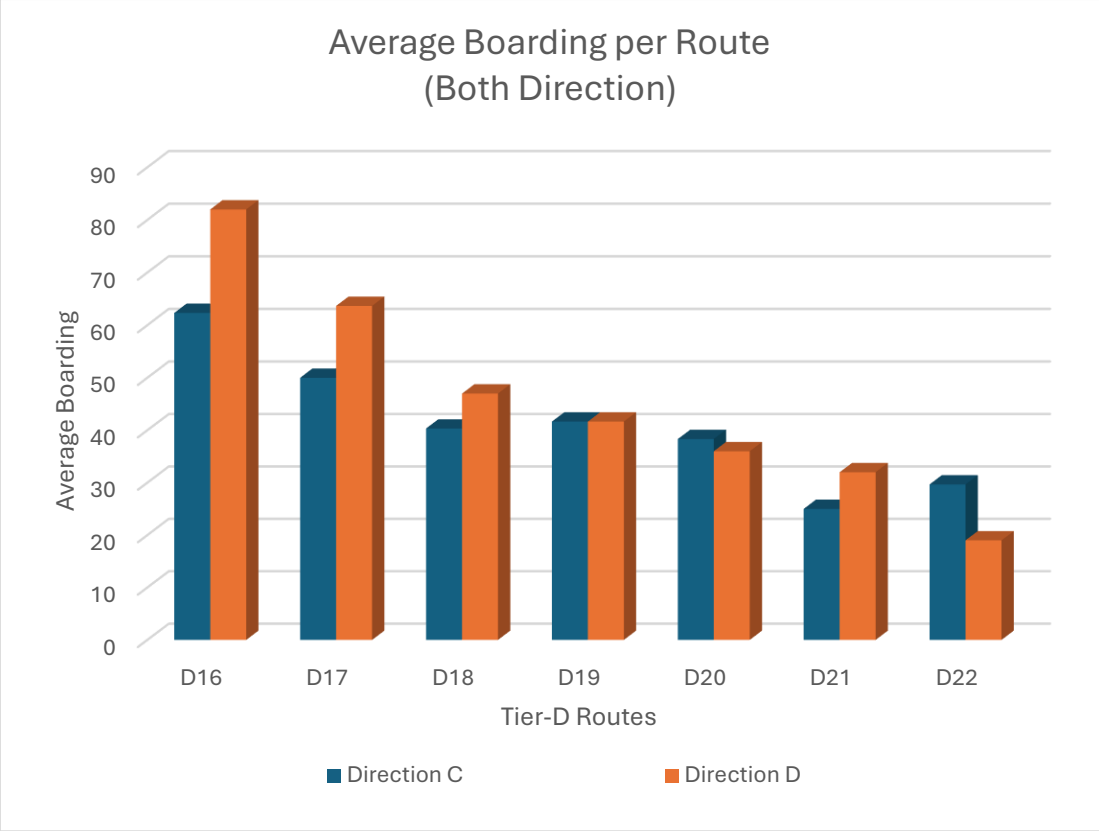


Figure 27: Bar-Chart showing the Average Demand of Tier-D PT Routes

Similarly, the comparison between maximum passengers in vehicle during the trip and the actual seat capacity can be visualized through following graph.

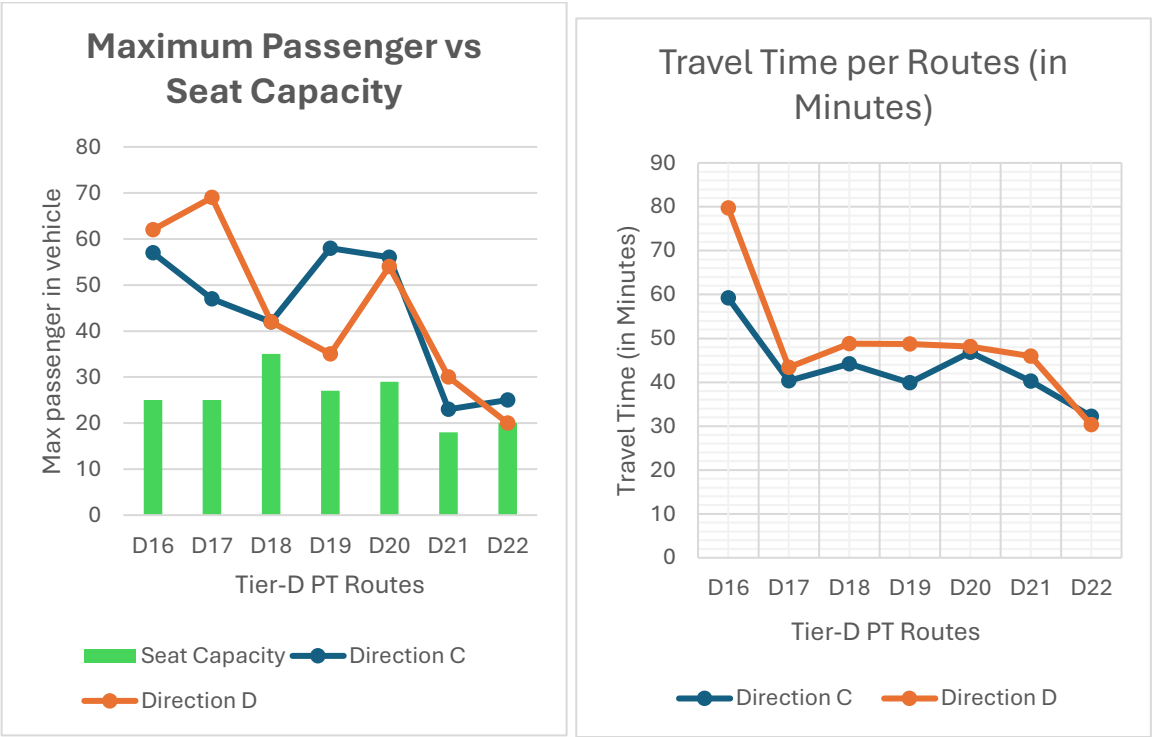


Figure 28: Chart showing distribution of Max pax vs seat Capacity & travel times of Tier-B Routes

Similarly, The heatmap showing the variation of VLR and DCR are shown as:

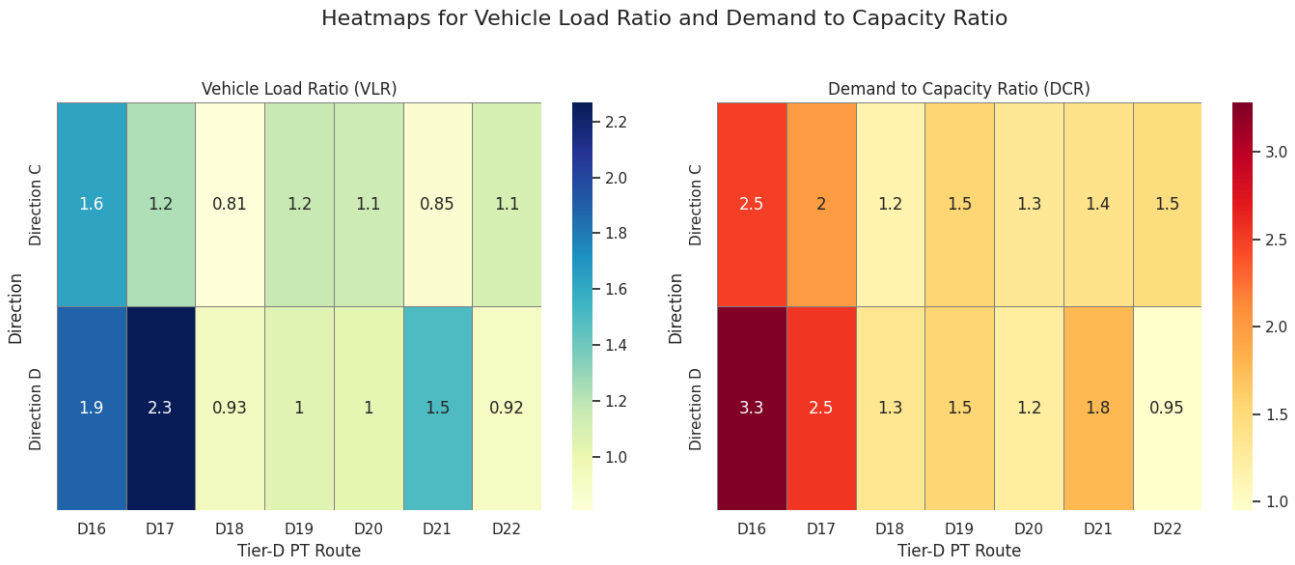

Heatmaps for Vehicle Load Ratio and Demand to Capacity Ratio
Vehicle Load Ratio (VLR)
Demand to Capacity Ratio (DCR)
Direction
Direction C
Direction D
1.6 1.2 0.81 1.2 1.1 0.85 1.1
1.9 2.3 0.93 1 1 1.5 0.92
2.5 2 1.2 1.5 1.3 1.4 1.5
3.3 2.5 1.3 1.5 1.2 1.8 0.95
D16 D17 D18 D19 D20 D21 D22
Tier-D PT Route
2.2 2.0 1.8 1.6 1.4 1.2 1.0
3.0 2.5 2.0 1.5 1.0

Figure 29: Heatmaps of VLR and DCR of Tier-B PT Routes

3.3 Weight Assignment & Route Hierarchy Using AHP

3.3.1 Saaty Scale and Triangular Fuzzy Number

AHP is a Multi Criteria Decision Making (MCDM) method proposed by Saaty in 1980 along with the hierarchical decision-making procedure. Hierarchical decision-making was developed by Kocaoglu, 1983 and based on the same concept as AHP (Saaty, 1987) but uses different pair wise comparison scales and judgment quantification techniques. AHP was developed to solve complex MCDM problems involving multiple qualitative and quantitative criteria. In AHP, the parameters are compared against each other and a preference on one over other is marked by a certain scale, generally 1-9 Saaty Scale, ranging in Linguistic term from “Equally Important” to “Very strongly important”. Table below shows the Saaty scale value and Triangular Fuzzy Number (TFN).

Table 11: Saaty Scale and Triangular Fuzzy Number

Definition	Intensity of Importance (Number)	In terms of Fuzzy Number (TFN)
Equally Important	1	(1, 1, 1)
Slightly More Important	3	(2, 3, 4)
Fairly/Moderately Important	5	(4, 5, 6)
Strongly Important	7	(6, 7, 8)
Very Strongly Important	9	(9, 9, 9)
Reciprocal of	1/m	(1/u, 1/m, 1/l)

In our study, the following parameters (denoted by specific symbols like C1, C2,...) is used and those are presented in the table below.

Table 12: Weighted Parameters

S.N	Parameter Code	Parameters	Benefit/ Cost	Remarks
1	**C1**	**Ridership (Demand Capacity ratio)**	Benefit	Higher is more critical
2	**C2**	**Vehicle Load Ratio (VLR)**	Benefit	Higher crowding is more critical
3	**C3**	**Route Length (km)**	Cost	Longer is generally worse for reliability/ops
4	**C4**	**Travel Time (minutes)**	Cost	Longer is worse
5	**C5**	**Total Stops along the route**	Cost	More stops tend to slow service unless justified by access
6	**C6**	**Route Overlap Score**	Cost	Higher overlap reliance is more critical

3.3.2 Expert-Informed Judgments

In this study, several experts were consulted to compare the criteria and judge which one is more important and by how much. Their opinions were expressed using triangular fuzzy numbers (TFNs), such as (4,5,6), which represent a lower bound, a most likely value, and an upper bound. From these consultations, the following weighted results were obtained. The consensus judgments and their justifications are as follows:

- **C1 vs. C2 (4,5,6)**

  Ridership is considered more important than load ratio because the total number of passengers has greater influence on planning.

- **C1 vs. C3 (6,7,8)**

  Ridership is given higher priority than corridor length. Even a shorter corridor can be prioritized if it carries more passengers.

- **C1 vs. C4 (6,7,8)**

  High-demand routes are prioritized even if they take more travel time.

- **C1 vs. C5 (6,7,8)**

  The number of stops matters, but ridership plays the dominant role.

- **C1 vs. C6 (4,5,6)**

  Ridership is generally more important than network overlap, though overlap is still a factor.

- **C2 vs. C3 (4,5,6)**

  Crowding levels (load ratio) are considered more important than the physical length of a corridor.

- **C2 vs. C4 (2,3,4)**

  Load ratio has slightly more weight, but travel time also matters for service quality.

- **C2 vs. C5 (4,5,6)**

  Load ratio is considered more important than the number of stops.

- **C2 vs. C6 (2,3,4)**

  Load ratio is judged as a little more important than overlap.

- **C6 vs. C4 (4,5,6)**

  Overlap in shared corridors is more critical than just travel time.

- **C6 vs. C3 (4,5,6)**

  Overlap is seen as more important than corridor length.

- **C6 vs. C5 (4,5,6)**

  Overlap has greater weight than the number of stops.

- **C4 vs. C3 (2,3,4)**

  Travel time is more important to passengers than the total length of a corridor.

- **C4 vs. C5 (2,3,4)**

  Travel time is more critical than stop density.

- **C3 vs. C5 (2,3,4)**

  The number of stops is given slightly more importance than the corridor length.

3.3.3 Fuzzy Pairwise Matrix

From these judgments, the **upper, middle and lower triangle** of the 6×6 pairwise matrix was filled using the TFNs. The **diagonal entries** are all (1,1,1), since each criterion is equally important with itself. The fuzzy pairwise matrix is constructed as shown below:

Table 13: Fuzzy Pairwise Matrix

Parameters	C1	C2	C3	C4	C5	C6
C1	(1.000, 1.000, 1.000)	(4.000, 5.000, 6.000)	(6.000, 7.000, 8.000)	(6.000, 7.000, 8.000)	(6.000, 7.000, 8.000)	(4.000, 5.000, 6.000)
C2	(0.167, 0.200, 0.250)	(1.000, 1.000, 1.000)	(4.000, 5.000, 6.000)	(2.000, 3.000, 4.000)	(4.000, 5.000, 6.000)	(2.000, 3.000, 4.000)
C3	(0.125, 0.143, 0.167)	(0.167, 0.200, 0.250)	(1.000, 1.000, 1.000)	(0.250, 0.333, 0.500)	(2.000, 3.000, 4.000)	(0.167, 0.200, 0.250)
C4	(0.125, 0.143, 0.167)	(0.250, 0.333, 0.500)	(2.000, 3.000, 4.000)	(1.000, 1.000, 1.000)	(2.000, 3.000, 4.000)	(0.167, 0.200, 0.250)
C5	(0.125, 0.143, 0.167)	(0.167, 0.200, 0.250)	(0.250, 0.333, 0.500)	(0.250, 0.333, 0.500)	(1.000, 1.000, 1.000)	(0.167, 0.200, 0.250)
C6	(0.167, 0.200, 0.250)	(0.250, 0.333, 0.500)	(4.000, 5.000, 6.000)	(4.000, 5.000, 6.000)	(4.000, 5.000, 6.000)	(1.000, 1.000, 1.000)

The fuzzy AHP procedure was applied after constructing the expert-informed fuzzy pairwise comparison matrix to obtained weightage. Following standard steps were followed.

(i) Calculation of fuzzy geometric means

(ii) Normalization to obtain fuzzy weights

(iii) Defuzzification using the centroid method, and

(iv) Final normalization

3.3.4 Final Weights for Selected Parameters

Table below shows the priority weights for the six criteria and these values represent the final relative importance of the criteria under the fuzzy AHP framework.

Table 14: Final Weights of Selected Parameters

Code	Parameters	Weights
C1	Ridership (Demand Capacity Ratio)	**0.48599**
C2	Vehicle Load Ratio (VLR)	**0.20471**
C3	Route Length (km)	**0.04679**
C4	Travel Time (in minutes)	**0.07326**
C5	Total Stops along the route	**0.03288**
C6	Route Overlap Score	**0.15638**

3.3.5 Final Weightage and Hierarchy

- **Tier A – Long Routes (> 20 km)**

After calculating the final weighted scores, the Tier A routes were ranked based on their overall importance. A01 (Naya Buspark–Maharajgunj–Koteshwor–Banepa–Dhulikhel) ranked number 1 with a score of 59.704, reflecting its high passenger demand, long route coverage, and strategic connectivity across key nodes. A02 (Ringroad Circulation) followed as number 2 with 52.185, benefiting from moderate demand and high stop density. A04 (Bansbari–Suryabinayak–Koteshwor–Chabahil–Naya Buspark) scored 46.863, ranking number 3, balancing moderate ridership and route overlap. A03 (Thankot–Kalanki–Naya Buspark–Maharajgunj–Budhanilkantha) scored 36.648 and was placed number 4, reflecting comparatively lower demand and load ratio.

These rankings provide a rational basis for prioritizing Tier A corridors, helping planners identify routes that require the most attention for service improvements and operational planning.

Table 15: Hierarchy of Tier A Routes

Route Code	Route Name	C1 Demand Capacity Ratio	C2 Vehicle Load Ratio (VLR)	C3 Route Length (km)	C4 Travel Time (in minutes)	C5 Total No. of Stops	C6 Route Overlap Score	Total Weighted Score	Tier-wise Rank
A01	Naya Buspark-Maharajgunj-Koteshwor-Banepa-Dhulikhel	4.10	1.98	36.36	145.62	51	3.091	59.704	1
A02	Ringroad Circulation	3.71	1.14	27.42	147.65	63	3.727	52.185	2
A04	Bansbari (Bhaktapur)-Suryabinayak-Koteshwor-Chabahil -Naya Buspark	3.46	1.26	23.75	113.12	48	2.909	46.863	3
A03	Thankot-Kalanki-Naya Buspark-Maharajgunj-Budhanilkantha	2.35	1.04	23.37	116.28	43	2.000	36.648	4

- **Tier B – Medium-Long Routes (15 km-20 km)**

Based on the final weighted scores, the Tier B routes were ranked as follows: B05 (Tikathali–Balkumari–Koteshwor–Putalisadak–Baluwatar–Kapan–Phaikaa) scored the highest with 79.684 and was ranked number 1, reflecting its high passenger demand and strategic connectivity across key nodes. B08 (Sankhu–Chabahil–Gausala–Dillibazar–Bagbazar–NAC) followed with 56.082 as number 2, showing the importance of intermediate ridership and overlap in operational corridors. B06 (Balkot–Koteshwor–New Baneshwor–Tripureshwor–Kalanki–Swoyambhu) scored 55.482 and was ranked number 3, balancing moderate demand and route coverage. B07 (Sundarijal–Chabahil–Gausala–Dillibazar–Bagbazar–NAC) had 54.293, placing number 4, reflecting shorter route length but moderate overlap and ridership. B09 (Mulpani–Pepsicola–Koteshwor–New

Baneshwor–NAC) scored 47.577 and was ranked number 5, reflecting its lower ridership and route overlap compared to other Tier B routes.

These rankings are critical for operational planning, as they highlight which corridors require priority attention for frequency adjustment, fleet allocation, or infrastructure improvements, and are rationally derived from the combined effect of demand, load, route characteristics, travel time, stops, and overlap scores.

Table 16: Hierarchy of Tier B Routes

Route Code	Route Name	C1 Demand Capacity Ratio	C2 Vehicle Load Ratio (VLR)	C3 Route Length (km)	C4 Travel Time (in minutes)	C5 Total No. of Stops	C6 Route Overlap Score	Total Weighted Score	Tier-wise Rank
B05	Tikathali-Balkumari-Koteshwor-Putalisadak-Baluwatar-Kapan-Phaikaa	8.15	2.18	18.75	143.87	40	1.727	79.684	1
B08	Sankhu-Chabahil-Gausala-Dillibazar-Bagbazar-NAC	3.55	1.68	19.03	106.80	32	6.545	56.082	2
B06	Balkot-Koteshwor-New Baneshwor-Tripureshwor-Kalanki-Swoyambhu	4.08	2.46	18.18	101.18	41	1.818	55.482	3
B07	Sundarijal-Chabahil-Gausala-Dillibazar-Bagbazar-NAC	3.19	1.78	16.33	75.57	29	7.364	54.293	4
B09	Mulpani-Pepsicola-Koteshwor-New Baneshwor-NAC	2.69	1.63	15.46	92.32	29	5.727	47.577	5

- **Tier C– Medium-Short Routes (10 km-15 km)**

Based on the final weighted scores, the Tier C routes were ranked as follows: C10 (Tinpiple–Machhapokhari–Balaju–Lainchaur–NAC) scored the highest with 68.386 and was ranked number 1, reflecting strong demand, moderate vehicle load, and significant corridor overlap. C11 (Jhor–Nepaltar–Machhapokhari–Lainchaur–NAC) followed with 50.722 as number 2, showing moderate demand and overlap supporting its priority. C13 (Puspalal Buspark–Kirtipur–Balkhu–Kalimati–NAC) scored 48.358 and was ranked number 3, balancing passenger demand and travel time along the corridor. C14 (Thankot–Kalanki–Kalimati–NAC) scored 45.425 and ranked number 4, reflecting moderate ridership but longer travel time. C12 (Lagankhel–Gwarko–Sanagaun–Lubhu–Dhungin) scored 35.897 and was ranked number 5, while C15 (Lagankhel–Satdobato–Harisiddhi–Godawari) had the lowest score of 32.625 and ranked number 6, primarily due to lower demand and overlap.

These rankings provide a rational basis for prioritizing corridors in Tier C, highlighting where operational focus, scheduling adjustments, or service improvements are most needed.

Table 17: Hierarchy of Tier C Routes

Route Code	Route Name	C1 Demand Capacity Ratio (DCR)	C2 Vehicle Load Ratio (VLR)	C3 Route Length (km)	C4 Travel Time (in minutes)	C5 Total Stops	C6 Route Overlap Score	Total Weighted Score	Tier-wise Rank
C10	Tinpiple-Machhapokhari-Balaju-Lainchaur-NAC	4.56	2.80	11.12	69.73	25	7.182	68.386	1
C11	Jhor-Nepaltar-Machhapokhari-Lainchaur-NAC	2.56	2.06	11.65	65.25	21	7.182	50.722	2
C13	Puspalal Buspark-Kirtipur-Balkhu-Kalimati-NAC	2.81	2.22	11.77	66.70	18	4.727	48.358	3
C14	Thankot-Kalanki-Kalimati-NAC	2.11	2.44	13.27	42.82	23	4.909	45.425	4
C12	Lagankhel-Gwarko-Sanagaun-Lubhu-Dhungin	2.81	1.81	10.75	54.67	23	0.273	35.897	5
C15	Lagankhel-Satdobato-Harisiddhi-Godawari	2.31	2.00	10.54	38.65	11	0.182	32.625	6

- **Tier D – Short Routes (≤ 10 km)**

Based on the final weighted scores, the Tier D routes were ranked as follows: D16 (Naya Buspark–Gongabu–Putalisadak–Purano Baneshwor–Sinamangal) scored the highest with 63.359 and was ranked number 1, reflecting strong ridership, moderate vehicle load, and significant corridor overlap. D17 (Raniban–Dhungedhara–Balaju–Lainchaur–NAC) followed with 55.065 as number 2, showing moderate demand and overlap supporting its priority. D19 (Goldhunga–Machhapokhari–Balaju–Lainchaur–NAC) scored 48.701 and was ranked number 3, balancing demand and travel time. D22 (Lagankhel–Jawalakhel–Maitighar–Ratnapark) scored 30.767 and was ranked number 6, while D18 (Budhanilkantha–Maharajgunj–Lazimpat–Ratnapark) had the lowest score of 28.384 and ranked number 7, reflecting relatively lower demand and vehicle load.

These rankings provide a rational and data-informed basis for operational planning, helping identify which corridors in Tier D require more focus for scheduling, fleet allocation, or service improvements.

Table 18: Hierarchy of Tier D Routes

Route Code	Route Name	C1 Demand Capacity Ratio (DCR)	C2 Vehicle Load Ratio (VLR)	C3 Route Length (km)	C4 Travel Time (in minutes)	C5 Total No. of Stops	C6 Route Overlap Score	Total Weighted Score	Tier-wise Rank
D16	Naya Buspark-Gongabu-Putalisadak-Purano Baneshwor-Sinamangal	3.88	2.48	9.77	82.72	21	7.727	63.359	1
D17	Raniban-Dhungedhara-Balaju-Lainchaur-NAC	2.92	2.76	6.43	46.48	14	6.727	55.065	2
D19	Goldhunga-Machhapokhari-Balaju-Lainchaur-NAC	2.44	2.15	9.30	39.02	18	7.091	48.701	3
D21	Chandeshwori-Tokha-Samakhusi-Lainchaur-NAC	2.06	1.61	10.22	53.20	11	6.364	41.441	4
D20	Lagankhel-Satdobato-Thecho-Chapagaun-Takhel Chautara	2.21	1.93	9.71	55.42	14	0.273	32.557	5
D22	Lagankhel-Jawalakhel-Maitighar-Ratnapark	1.55	1.25	5.77	31.35	10	4.727	30.767	6
D18	Budhanilkantha-Maharajgunj-Lazimpat-Ratnapark	1.69	1.20	9.81	50.32	16	2.455	28.384	7

3.4 GIS Based Spatial Visualization

The public transport routes were classified into four hierarchical tiers based on their lengths and subsequently visualized using QGIS. This spatial mapping enabled a clear understanding of the geographical coverage, service density, and alignment patterns of the routes within the Kathmandu Valley.

The GIS-based approach enabled the conversion of raw data—such as GPS tracks, survey points, and demographic layers—into interactive maps that support both technical analysis and stakeholder engagement. The following process were carried out in GIS:

- **Route Digitization**
- **Symbolization**
- **Overlay Layers**
- **Heatmaps**

This geospatial representation provided a solid foundation for advanced spatial analysis and thematic mapping. Advanced GIS functions were used to generate heatmaps of both ridership intensity and service density.

The ridership heatmap, overlaid with the classified route tiers, reveals insightful spatial trends:

- High-demand zones were concentrated around employment centers, educational institutions, and dense commercial hubs, such as NAC/Ratnapark. New Baneshwor, and Putalisadak. These areas exhibit intense travel activity, particularly during peak hours.
- Tier A and Tier B routes overlap strongly with these high-demand corridors, affirming their critical role in network efficiency.
- Peripheral areas, show sparse service coverage. These areas appear as unserved or underserved pockets, indicating a potential gap in equitable accessibility.

- The spatial juxtaposition of ridership intensity and route hierarchy also reveals overlapping segments, particularly in the core city, suggesting opportunities to optimize routes and reduce redundancy.

The visual outputs created through GIS were more than just illustrative—they played a central role in validating the analytical results from performance indicators, route classification, and network modeling. These visual maps can be served as intuitive tools for explaining complex concepts, allowing policymakers and transit authorities to visually grasp route gaps, redundancies, or overlaps. This improved communication helped bridge the gap between technical findings and practical implementation.

The detail spatial visualization of the 22 public transportation routes inside Kathmandu valley conducted in the form of GIS Maps are attached in the **ANNEX-II** of this report.

Chapter 4
CONCLUSION

This study presents a systematic and analytical framework for classifying and evaluating the public transportation network of Kathmandu Valley through a multicriteria approach. By focusing on 22 public transport routes spanning across Kathmandu, Lalitpur, and Bhaktapur districts, the study aimed to develop a tiered route hierarchy that could support more efficient planning, investment, and operational strategies. Drawing upon a combination of data-driven indicators, multicriteria decision-making techniques, and spatial analysis, the research offers critical insights into the current performance and structure of the urban transit network.

Through comprehensive descriptive analysis of key service and operational indicators—such as route length, number of stops, headway, ridership, vehicle load ratio, operational hours, stop density, route overlap, travel time variability, and connectivity index—the study revealed the wide heterogeneity among existing routes. These indicators were quantified using data collected across three different time periods in a day (morning peak, day off-peak, and evening peak) and in both directions, offering a dynamic view of operational realities and user demand patterns. The variability among routes underscored the necessity for differentiated strategies in managing short, medium, and long-distance services.

A tier-based classification system was developed, organizing the 22 routes into four distinct categories based on route length and other operational characteristics. This classification helped in identifying the unique role each tier plays within the overall transport ecosystem—ranging from high-demand trunk corridors (Tier-A) to short-distance local routes (Tier-D) that support neighborhood-level access and last-mile connectivity. Descriptive statistics for each tier further highlighted differences in average demand, service frequency, and route efficiency, facilitating more nuanced route comparisons.

GIS-based spatial visualization added an essential layer of geographic understanding to the classification framework. By mapping the routes and associated ridership heatmaps, the analysis identified key movement corridors, zones of high demand, and spatial gaps in service. Long routes aligned with primary arterial roads, while medium and short routes revealed overlapping services and redundancy in certain central zones, and conversely, service gaps in peripheral and underserved areas. The spatial hierarchy map provides planners with a powerful tool to align infrastructure investment and service improvements with actual user needs and demand flows.

The classification and evaluation of the public transport routes using multicriteria techniques such as AHP not only validated the indicator weighting but also laid the foundation for objective and transparent decision-making in future network development. The findings underscore the potential of combining data analytics, decision models, and spatial tools to address the pressing challenges of congestion, inefficiency, and inequity in Kathmandu's public transport system.

Overall, this study contributes a replicable methodology for urban transit network assessment and highlights the need for evidence-based planning in the evolution of Kathmandu Valley's mobility landscape. With appropriate institutional support and policy translation, the proposed analytical hierarchy can guide phased restructuring of the network, targeted investments, and improved service delivery to promote a more inclusive, efficient, and sustainable urban transportation system.

REFERENCES

Banerjee, N., Morton, A., & Akartunalı, K. (2020). Passenger demand forecasting in scheduled transportation. *European Journal of Operational Research*, *286*(3), 797–810. https://doi.org/10.1016/j.ejor.2019.10.032

Ceder, A., & Varghese, J. (2011). Analysis of Passenger-Ferry Routes Using Connectivity Measures. *Journal of Public Transportation*, *14*(1), 29–55. https://doi.org/10.5038/2375-0901.14.1.2

Cervero, R. (2013). Bus rapid transit (BRT): An efficient and competitive mode of public transport. IURD Working Paper.

De França Marques, S., Pitombo, C. S., & Gómez-Hernández, J. J. (2024). Spatial Modeling of Travel Demand Accounting for Multicollinearity and Different Sampling Strategies: A Stop-Level Case Study. *Journal of Advanced Transportation*, *2024*(1), 7967141. https://doi.org/10.1155/2024/7967141

Li, M., Kwan, M.-P., Hu, W., Li, R., & Wang, J. (2023). Examining the effects of station-level factors on metro ridership using multiscale geographically weighted regression. *Journal of Transport Geography*, *113*, 103720. https://doi.org/10.1016/j.jtrangeo.2023.103720

Litman, T. (2017). Evaluating public transit benefits and costs. Victoria Transport Policy Institute.

Moslem, S., & Duleba, S. (2018). Application of AHP for evaluating passenger demand for public transport improvements in Mersin, Turkey. *Pollack Periodica*, *13*(2), 67–76. https://doi.org/10.1556/606.2018.13.2.7

Pulugurtha, S. S., & Agurla, M. (2012). Assessment of Models to Estimate Bus-Stop Level Transit Ridership using Spatial Modeling Methods. *Journal of Public Transportation*, *15*(1), 33–52. https://doi.org/10.5038/2375-0901.15.1.3

Sun, W., Schmöcker, J.-D., & Fukuda, K. (2021). Estimating the route-level passenger demand profile from bus dwell times. *Transportation Research Part C: Emerging Technologies*, *130*, 103273. https://doi.org/10.1016/j.trc.2021.103273

Saaty, T. L. (2008). Decision making with the analytic hierarchy process. International Journal of Services Sciences, 1(1), 83–98.

Tufte, E. R. (2001). The visual display of quantitative information. Graphics Press.

Vuchic, V. R. (2005). Urban transit: Operations, planning, and economics. Wiley.

ANNEX-I: DATASHEETS

OVERALL DATA (ALL 24 PUBLIC TRANSPORTATION ROUTES THREE TRIPS IN BOTH DIRECTION)

Route No	Route Code	Route Name	RoundTrip	Direction Config	Direction	Vehicle Type	Seat Capacity	Operator	Total Stations	Boarding Total	Max Pax Onboard	Vehicle Load Ratio	Demand Capacity Ratio	Start Time	End Time	Length (km)	Travel Time (in min)	Travel Time (h:m:s)	Average Speed (km/hr)
A01	A01MA	Naya Buspark-Maharajgunj-Koteshwor-Banepa-Dhulikhel	1st (Morning Peak)	A	Dhulikhel-Naya Buspark	Bus	40	Mayur Yatayat	51	137	60	1.50	3.43	8:16:48	10:58:48	36.26	162.00	02:42:00	13.43
A01	A01DA	Naya Buspark-Maharajgunj-Koteshwor-Banepa-Dhulikhel	2nd (Day Off-Peak)	A	Dhulikhel-Naya Buspark	Bus	40	Mayur Yatayat	51	183	60	1.50	4.58	15:36:19	18:15:26	36.41	159.12	02:39:07	13.73
A01	A01EA	Naya Buspark-Maharajgunj-Koteshwor-Banepa-Dhulikhel	3rd (Evening Peak)	A	Dhulikhel-Naya Buspark	Bus	40	Mayur Yatayat	51	159	51	1.28	3.98	15:52:24	18:21:37	36.03	149.22	02:29:13	14.49
A01	A01MB	Naya Buspark-Maharajgunj-Koteshwor-Banepa-Dhulikhel	1st (Morning Peak)	B	Naya Buspark-Dhulikhel	Bus	40	Mayur Yatayat	51	164	49	1.23	4.10	11:45:19	14:27:00	36.48	161.68	02:41:41	13.54
A01	A01DB	Naya Buspark-Maharajgunj-Koteshwor-Banepa-Dhulikhel	2nd (Day Off-Peak)	B	Naya Buspark-Dhulikhel	Bus	40	Mayur Yatayat	51	164	79	1.98	4.10	14:57:52	17:23:29	36.36	145.62	02:25:37	14.98
A01	A01EB	Naya Buspark-Maharajgunj-Koteshwor-Banepa-Dhulikhel	3rd (Evening Peak)	B	Naya Buspark-Dhulikhel	Bus	40	Mayur Yatayat	51	151	55	1.38	3.78	15:25:01	18:08:12	36.08	163.18	02:43:11	13.27
A02	A02MCL	Ringroad Circulation	1st (Morning Peak)	CL	Koteshwor-Koteshwor	Bus	35	Mahanagar Yatayat	63	130	40	1.14	3.71	9:36:03	12:03:42	27.42	147.65	02:27:39	11.14
A02	A02DCL	Ringroad Circulation	2nd (Day Off-Peak)	CL	Koteshwor-Koteshwor	Bus	35	Mahanagar Yatayat	63	146	28	0.80	4.17	14:09:52	16:54:54	27.58	165.03	02:45:02	10.03
A02	A02ECL	Ringroad Circulation	3rd (Evening Peak)	CL	Koteshwor-Koteshwor	Bus	35	Mahanagar Yatayat	63	120	33	0.94	3.43	17:25:25	20:19:32	27.32	174.12	02:54:07	9.41
A03	A03MA	Thankot-Kalanki-Naya Buspark-Maharajgunj-Budhanilkantha	1st (Morning Peak)	A	Budhanilkantha-Thankot	Bus	52	Sajha Yatayat	43	108	48	0.92	2.08	10:11:00	11:56:05	23.22	105.08	01:45:05	13.26
A03	A03DA	Thankot-Kalanki-Naya Buspark-Maharajgunj-Budhanilkantha	2nd (Day Off-Peak)	A	Budhanilkantha-Thankot	Bus	52	Sajha Yatayat	43	105	51	0.98	2.02	13:16:29	15:09:32	24.33	113.05	01:53:03	12.91
A03	A03EA	Thankot-Kalanki-Naya Buspark-Maharajgunj-Budhanilkantha	3rd (Evening Peak)	A	Budhanilkantha-Thankot	Bus	52	Sajha Yatayat	43	122	54	1.04	2.35	16:34:40	18:30:57	23.37	116.28	01:56:17	12.06
A03	A03MB	Thankot-Kalanki-Naya Buspark-Maharajgunj-Budhanilkantha	1st (Morning Peak)	B	Thankot-Budhanilkantha	Bus	52	Sajha Yatayat	43	115	53	1.02	2.21	8:10:33	9:53:00	23.25	102.45	01:42:27	13.62
A03	A03DB	Thankot-Kalanki-Naya Buspark-Maharajgunj-Budhanilkantha	2nd (Day Off-Peak)	B	Thankot-Budhanilkantha	Bus	52	Sajha Yatayat	43	82	30	0.58	1.58	15:23:14	17:03:16	23.95	100.03	01:40:02	14.37
A03	A03EB	Thankot-Kalanki-Naya Buspark-Maharajgunj-Budhanilkantha	3rd (Evening Peak)	B	Thankot-Budhanilkantha	Bus	52	Sajha Yatayat	43	99	53	1.02	1.90	14:31:02	16:20:34	23.25	109.53	01:49:32	12.73
A04	A04MA	Bansbari (Bhaktapur)-Suryabinayak-Koteshwor-Chabahil -Naya Buspark	1st (Morning Peak)	A	Bansbari (Bhaktapur)-Naya Buspark	Bus	35	Khowpa Bhaktapur Yatayat	48	101	49	1.40	2.89	9:07:18	10:47:23	23.78	100.08	01:40:05	14.26
A04	A04DA	Bansbari (Bhaktapur)-Suryabinayak-Koteshwor-Chabahil -Naya Buspark	2nd (Day Off-Peak)	A	Bansbari (Bhaktapur)-Naya Buspark	Bus	35	Khowpa Bhaktapur Yatayat	48	71	37	1.06	2.03	14:08:49	16:00:52	23.79	112.05	01:52:03	12.74
A04	A04EA	Bansbari (Bhaktapur)-Suryabinayak-Koteshwor-Chabahil -Naya Buspark	3rd (Evening Peak)	A	Bansbari (Bhaktapur)-Naya Buspark	Bus	35	Khowpa Bhaktapur Yatayat	48	91	42	1.20	2.60	16:11:11	18:06:20	24.06	115.15	01:55:09	12.54
A04	A04MB	Bansbari (Bhaktapur)-Suryabinayak-Koteshwor-Chabahil -Naya Buspark	1st (Morning Peak)	B	Naya Buspark-Bansbari (Bhaktapur)	Bus	35	Khowpa Bhaktapur Yatayat	48	121	44	1.26	3.46	11:36:59	13:30:06	23.75	113.12	01:53:07	12.60
A04	A04DB	Bansbari (Bhaktapur)-Suryabinayak-Koteshwor-Chabahil -Naya Buspark	2nd (Day Off-Peak)	B	Naya Buspark-Bansbari (Bhaktapur)	Bus	35	Khowpa Bhaktapur Yatayat	48	80	39	1.11	2.29	17:06:20	18:58:54	23.72	112.57	01:52:34	12.64
A04	A04EB	Bansbari (Bhaktapur)-Suryabinayak-Koteshwor-Chabahil -Naya Buspark	3rd (Evening Peak)	B	Naya Buspark-Bansbari (Bhaktapur)	Bus	35	Khowpa Bhaktapur Yatayat	48	96	57	1.63	2.74	18:20:13	20:10:10	24.10	109.95	01:49:57	13.15
B05	B05MC	Tikathali-Balkumari-Koteshwor-Putalisadak-Baluwatar-Kapan-Phaikaa	1st (Morning Peak)	C	Phaikaa-Tikathali	Bus	33	Nepal Yatayat Express	39	123	51	1.55	3.73	10:33:32	12:19:35	19.65	106.05	01:46:03	11.12
B05	B05DC	Tikathali-Balkumari-Koteshwor-Putalisadak-Baluwatar-Kapan-Phaikaa	2nd (Day Off-Peak)	C	Phaikaa-Tikathali	Bus	33	Nepal Yatayat Express	39	122	69	2.09	3.70	15:39:52	17:30:04	19.84	110.20	01:50:12	10.80
B05	B05EC	Tikathali-Balkumari-Koteshwor-Putalisadak-Baluwatar-Kapan-Phaikaa	3rd (Evening Peak)	C	Phaikaa-Tikathali	Bus	33	Nepal Yatayat Express	39	217	78	2.36	6.58	17:01:40	19:03:42	19.82	122.03	02:02:02	9.75
B05	B05MD	Tikathali-Balkumari-Koteshwor-Putalisadak-Baluwatar-Kapan-Phaikaa	1st (Morning Peak)	D	Tikathali-Phaikaa	Bus	33	Nepal Yatayat Express	40	148	59	1.79	4.48	8:34:08	10:11:04	20.39	96.93	01:36:56	12.62
B05	B05DD	Tikathali-Balkumari-Koteshwor-Putalisadak-Baluwatar-Kapan-Phaikaa	2nd (Day Off-Peak)	D	Tikathali-Phaikaa	Bus	33	Nepal Yatayat Express	40	71	34	1.03	2.15	13:31:40	15:13:54	19.53	102.23	01:42:14	11.46
B05	B05ED	Tikathali-Balkumari-Koteshwor-Putalisadak-Baluwatar-Kapan-Phaikaa	3rd (Evening Peak)	D	Tikathali-Phaikaa	Bus	33	Nepal Yatayat Express	40	269	72	2.18	8.15	14:29:58	16:53:50	18.75	143.87	02:23:52	7.82
B06	B06MD	Balkot-Koteshwor-New Baneshwor-Tripureshwor-Kalanki-Swoyambhu	1st (Morning Peak)	D	Balkot-Swoyambhu	Mini Bus	26	Subhakamana Yatayat	41	85	48	1.85	3.27	8:14:57	9:52:58	18.40	98.02	01:38:01	11.26
B06	B06DD	Balkot-Koteshwor-New Baneshwor-Tripureshwor-Kalanki-Swoyambhu	2nd (Day Off-Peak)	D	Balkot-Swoyambhu	Mini Bus	26	Subhakamana Yatayat	41	84	32	1.23	3.23	12:22:31	14:04:31	18.08	102.00	01:42:00	10.64
B06	B06ED	Balkot-Koteshwor-New Baneshwor-Tripureshwor-Kalanki-Swoyambhu	3rd (Evening Peak)	D	Balkot-Swoyambhu	Mini Bus	26	Subhakamana Yatayat	41	46	26	1.00	1.77	14:59:20	16:35:51	17.89	96.52	01:36:31	11.12
B06	B06MC	Balkot-Koteshwor-New Baneshwor-Tripureshwor-Kalanki-Swoyambhu	1st (Morning Peak)	C	Swoyambhu-Balkot	Mini Bus	26	Subhakamana Yatayat	41	94	38	1.46	3.62	10:35:59	12:12:03	18.51	96.07	01:36:04	11.56
B06	B06DC	Balkot-Koteshwor-New Baneshwor-Tripureshwor-Kalanki-Swoyambhu	2nd (Day Off-Peak)	C	Swoyambhu-Balkot	Mini Bus	26	Subhakamana Yatayat	41	108	57	2.19	4.15	14:30:41	16:12:52	18.39	102.18	01:42:11	10.80
B06	B06EC	Balkot-Koteshwor-New Baneshwor-Tripureshwor-Kalanki-Swoyambhu	3rd (Evening Peak)	C	Swoyambhu-Balkot	Mini Bus	26	Subhakamana Yatayat	41	106	64	2.46	4.08	16:56:48	18:37:59	18.18	101.18	01:41:11	10.78

OVERALL DATA (ALL 24 PUBLIC TRANSPORTATION ROUTES THREE TRIPS IN BOTH DIRECTION)

Route No	Route Code	Route Name	RoundTrip	Direction Config	Direction	Vehicle Type	Seat Capacity	Operator	Total Stations	Boarding Total	Max Pax Onboard	Vehicle Load Ratio	Demand Capacity Ratio	Start Time	End Time	Length (km)	Travel Time (in min)	Travel Time (h:m:s)	Average Speed (km/hr)
B07	B07MA	Sundarijal-Chabahil-Gausala-Dillibazar-Bagbazar-NAC	1st (Morning Peak)	A	Sundarijal-NAC	Bus	32	Sundarimai Yatayat	29	74	44	1.38	2.31	8:37:30	9:54:49	14.98	77.32	01:17:19	11.63
B07	B07DA	Sundarijal-Chabahil-Gausala-Dillibazar-Bagbazar-NAC	2nd (Day Off-Peak)	A	Sundarijal-NAC	Bus	32	Sundarimai Yatayat	29	57	40	1.25	1.78	13:07:53	14:41:27	15.08	93.57	01:33:34	9.67
B07	B07EA	Sundarijal-Chabahil-Gausala-Dillibazar-Bagbazar-NAC	3rd (Evening Peak)	A	Sundarijal-NAC	Bus	32	Sundarimai Yatayat	29	76	54	1.69	2.38	16:56:55	18:28:24	14.79	91.48	01:31:29	9.70
B07	B07MB	Sundarijal-Chabahil-Gausala-Dillibazar-Bagbazar-NAC	1st (Morning Peak)	B	NAC-Sundarijal	Bus	32	Sundarimai Yatayat	29	52	32	1.00	1.63	10:45:58	11:18:00	15.71	32.03	00:32:02	29.42
B07	B07DB	Sundarijal-Chabahil-Gausala-Dillibazar-Bagbazar-NAC	2nd (Day Off-Peak)	B	NAC-Sundarijal	Bus	32	Sundarimai Yatayat	29	93	56	1.75	2.91	14:37:21	15:59:54	16.38	82.55	01:22:33	11.91
B07	B07EB	Sundarijal-Chabahil-Gausala-Dillibazar-Bagbazar-NAC	3rd (Evening Peak)	B	NAC-Sundarijal	Bus	32	Sundarimai Yatayat	29	102	57	1.78	3.19	18:32:39	19:48:13	16.33	75.57	01:15:34	12.97
B08	B08MA	Sankhu-Chabahil-Gausala-Dillibazar-Bagbazar-NAC	1st (Morning Peak)	A	Sankhu-NAC	Bus	31	Sankhu Salinadi Yatayat	30	67	36	1.16	2.16	8:58:36	10:14:24	17.98	75.80	01:15:48	14.23
B08	B08DA	Sankhu-Chabahil-Gausala-Dillibazar-Bagbazar-NAC	2nd (Day Off-Peak)	A	Sankhu-NAC	Bus	31	Sankhu Salinadi Yatayat	30	56	33	1.06	1.81	13:55:41	15:24:34	18.19	88.88	01:28:53	12.28
B08	B08EA	Sankhu-Chabahil-Gausala-Dillibazar-Bagbazar-NAC	3rd (Evening Peak)	A	Sankhu-NAC	Bus	31	Sankhu Salinadi Yatayat	30	41	29	0.94	1.32	15:07:39	16:38:09	18.12	90.50	01:30:30	12.01
B08	B08MB	Sankhu-Chabahil-Gausala-Dillibazar-Bagbazar-NAC	1st (Morning Peak)	B	NAC-Sankhu	Bus	31	Sankhu Salinadi Yatayat	32	39	25	0.81	1.26	10:15:34	11:41:12	18.96	85.63	01:25:38	13.28
B08	B08DB	Sankhu-Chabahil-Gausala-Dillibazar-Bagbazar-NAC	2nd (Day Off-Peak)	B	NAC-Sankhu	Bus	31	Sankhu Salinadi Yatayat	32	110	52	1.68	3.55	15:28:36	17:15:24	19.03	106.80	01:46:48	10.69
B08	B08EB	Sankhu-Chabahil-Gausala-Dillibazar-Bagbazar-NAC	3rd (Evening Peak)	B	NAC-Sankhu	Bus	31	Sankhu Salinadi Yatayat	32	62	24	0.77	2.00	16:42:07	18:14:42	18.81	92.58	01:32:35	12.19
B09	B09MA	Mulpani-Pepsicola-Koteshwor-New Baneshwor-NAC	1st (Morning Peak)	A	Mulpani-NAC	Bus	32	Chhetriya Upatyaka Yatayat	29	86	52	1.63	2.69	8:50:01	10:22:20	15.46	92.32	01:32:19	10.05
B09	B09DA	Mulpani-Pepsicola-Koteshwor-New Baneshwor-NAC	2nd (Day Off-Peak)	A	Mulpani-NAC	Bus	32	Chhetriya Upatyaka Yatayat	29	54	34	1.06	1.69	12:30:59	13:46:06	15.35	75.12	01:15:07	12.26
B09	B09EA	Mulpani-Pepsicola-Koteshwor-New Baneshwor-NAC	3rd (Evening Peak)	A	Mulpani-NAC	Bus	32	Chhetriya Upatyaka Yatayat	29	70	29	0.91	2.19	16:18:27	17:40:05	15.40	81.63	01:21:38	11.32
B09	B09MB	Mulpani-Pepsicola-Koteshwor-New Baneshwor-NAC	1st (Morning Peak)	B	NAC-Mulpani	Bus	32	Chhetriya Upatyaka Yatayat	29	60	37	1.16	1.88	10:23:32	11:43:42	16.92	80.17	01:20:10	12.66
B09	B09DB	Mulpani-Pepsicola-Koteshwor-New Baneshwor-NAC	2nd (Day Off-Peak)	B	NAC-Mulpani	Bus	32	Chhetriya Upatyaka Yatayat	29	44	23	0.72	1.38	13:46:46	15:18:03	16.68	91.28	01:31:17	10.96
B09	B09EB	Mulpani-Pepsicola-Koteshwor-New Baneshwor-NAC	3rd (Evening Peak)	B	NAC-Mulpani	Bus	32	Chhetriya Upatyaka Yatayat	29	59	49	1.53	1.84	17:42:18	19:03:57	14.15	81.65	01:21:39	10.40
C10	C10MC	Tinpiple-Machhapokhari-Balaju-Lainchaur-NAC	1st (Morning Peak)	C	Tinpiple-Ratnapark	MiniBus	25	Tarkeshwor Yatayat	25	114	70	2.80	4.56	10:45:01	11:54:45	11.12	69.73	01:09:44	9.57
C10	C10DC	Tinpiple-Machhapokhari-Balaju-Lainchaur-NAC	2nd (Day Off-Peak)	C	Tinpiple-Ratnapark	MiniBus	25	Tarkeshwor Yatayat	25	26	19	0.76	1.04	13:50:36	14:35:09	11.78	44.55	00:44:33	15.87
C10	C10EC	Tinpiple-Machhapokhari-Balaju-Lainchaur-NAC	3rd (Evening Peak)	C	Tinpiple-Ratnapark	MiniBus	25	Tarkeshwor Yatayat	25	17	10	0.40	0.68	16:40:03	17:17:53	11.91	37.83	00:37:50	18.89
C10	C10MD	Tinpiple-Machhapokhari-Balaju-Lainchaur-NAC	1st (Morning Peak)	D	Ratnapark-Tinpiple	MiniBus	25	Tarkeshwor Yatayat	24	86	42	1.68	3.44	11:59:53	13:09:46	11.20	69.88	01:09:53	9.62
C10	C10DD	Tinpiple-Machhapokhari-Balaju-Lainchaur-NAC	2nd (Day Off-Peak)	D	Ratnapark-Tinpiple	MiniBus	25	Tarkeshwor Yatayat	24	115	63	2.52	4.60	14:37:22	15:59:50	11.18	82.47	01:22:28	8.13
C10	C10ED	Tinpiple-Machhapokhari-Balaju-Lainchaur-NAC	3rd (Evening Peak)	D	Ratnapark-Tinpiple	MiniBus	25	Tarkeshwor Yatayat	24	98	62	2.48	3.92	17:32:03	18:42:02	11.46	69.98	01:09:59	9.83
C11	C11MC	Jhor-Nepaltar-Machhapokhari-Lainchaur-NAC	1st (Morning Peak)	C	Jhor-NAC	Bus	32	Tarkeshwor Yatayat	21	74	61	1.91	2.31	9:13:06	10:11:42	12.95	58.60	00:58:36	13.26
C11	C11DC	Jhor-Nepaltar-Machhapokhari-Lainchaur-NAC	2nd (Day Off-Peak)	C	Jhor-NAC	Bus	32	Tarkeshwor Yatayat	21	55	42	1.31	1.72	12:30:33	13:34:18	12.94	63.75	01:03:45	12.18
C11	C11EC	Jhor-Nepaltar-Machhapokhari-Lainchaur-NAC	3rd (Evening Peak)	C	Jhor-NAC	Bus	32	Tarkeshwor Yatayat	21	58	33	1.03	1.81	15:57:11	16:53:34	13.02	56.38	00:56:23	13.85
C11	C11MD	Jhor-Nepaltar-Machhapokhari-Lainchaur-NAC	1st (Morning Peak)	D	NAC-Jhor	Bus	32	Tarkeshwor Yatayat	21	31	24	0.75	0.97	10:17:42	10:59:59	11.93	42.28	00:42:17	16.92
C11	C11DD	Jhor-Nepaltar-Machhapokhari-Lainchaur-NAC	2nd (Day Off-Peak)	D	NAC-Jhor	Bus	32	Tarkeshwor Yatayat	21	68	52	1.63	2.13	13:40:18	14:46:26	11.63	66.13	01:06:08	10.56
C11	C11ED	Jhor-Nepaltar-Machhapokhari-Lainchaur-NAC	3rd (Evening Peak)	D	NAC-Jhor	Bus	32	Tarkeshwor Yatayat	21	82	66	2.06	2.56	16:59:34	18:04:49	11.65	65.25	01:05:15	10.71
C12	C12MB	Lagankhel-Gwarko-Sanagaun-Lubhu-Dhungin	1st (Morning Peak)	B	Lagankhel-Dhungin	MiniBus	27	Laganeshwor Mahadev Yatayat	23	42	28	1.04	1.56	8:53:36	9:39:31	10.42	45.92	00:45:55	13.62
C12	C12DB	Lagankhel-Gwarko-Sanagaun-Lubhu-Dhungin	2nd (Day Off-Peak)	B	Lagankhel-Dhungin	MiniBus	27	Laganeshwor Mahadev Yatayat	23	64	41	1.52	2.37	12:16:41	13:13:47	10.46	57.10	00:57:06	10.99
C12	C12EB	Lagankhel-Gwarko-Sanagaun-Lubhu-Dhungin	3rd (Evening Peak)	B	Lagankhel-Dhungin	MiniBus	27	Laganeshwor Mahadev Yatayat	23	46	41	1.52	1.70	16:10:19	17:11:35	10.24	61.27	01:01:16	10.03

OVERALL DATA (ALL 24 PUBLIC TRANSPORTATION ROUTES THREE TRIPS IN BOTH DIRECTION)

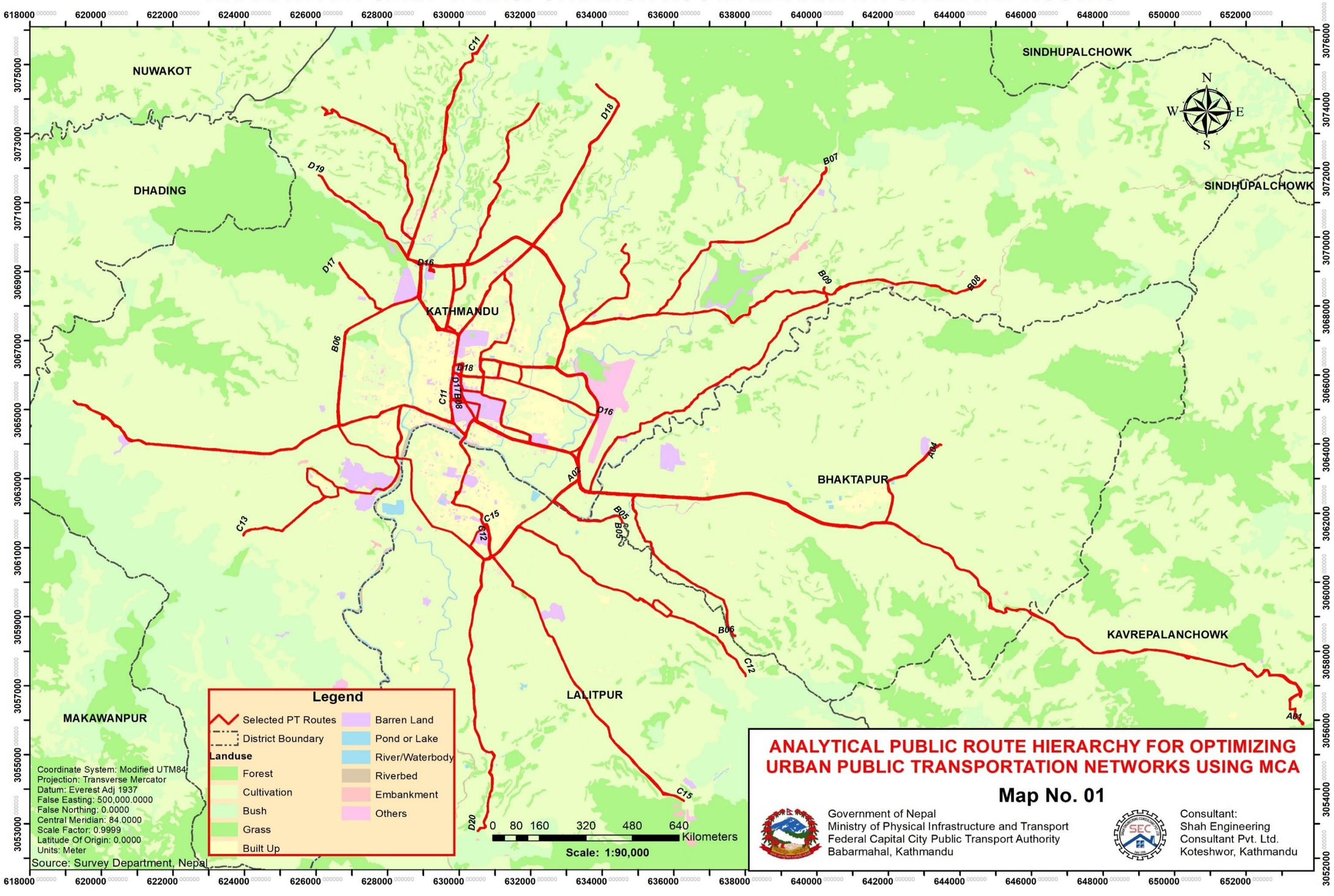
Route No	Route Code	Route Name	RoundTrip	Direction Config	Direction	Vehicle Type	Seat Capacity	Operator	Total Stations	Boarding Total	Max Pax Onboard	Vehicle Load Ratio	Demand Capacity Ratio	Start Time	End Time	Length (km)	Travel Time (in min)	Travel Time (h:m:s)	Average Speed (km/hr)
C12	C12MA	Lagankhel-Gwarko-Sanagaun-Lubhu-Dhungin	1st (Morning Peak)	A	Dhungin-Lagankhel	MiniBus	27	Laganeshwor Mahadev Yatayat	23	76	49	1.81	2.81	9:56:53	10:51:33	10.75	54.67	00:54:40	11.80
C12	C12DA	Lagankhel-Gwarko-Sanagaun-Lubhu-Dhungin	2nd (Day Off-Peak)	A	Dhungin-Lagankhel	MiniBus	27	Laganeshwor Mahadev Yatayat	23	51	36	1.33	1.89	13:34:12	14:40:54	10.85	66.70	01:06:42	9.76
C12	C12EA	Lagankhel-Gwarko-Sanagaun-Lubhu-Dhungin	3rd (Evening Peak)	A	Dhungin-Lagankhel	MiniBus	27	Laganeshwor Mahadev Yatayat	23	38	25	0.93	1.41	17:29:35	18:28:23	10.53	58.80	00:58:48	10.74
C13	C13MD	Puspalal Buspark-Kirtipur-Balkhu-Kalimati-NAC	1st (Morning Peak)	D	Pushpalal Buspark-NAC	MiniBus	27	Bagh Bahirab Yatayat	19	75	52	1.93	2.78	9:13:28	10:14:50	11.34	61.37	01:01:22	11.08
C13	C13DD	Puspalal Buspark-Kirtipur-Balkhu-Kalimati-NAC	2nd (Day Off-Peak)	D	Pushpalal Buspark-NAC	MiniBus	27	Bagh Bahirab Yatayat	19	48	40	1.48	1.78	13:20:56	14:02:48	11.34	41.87	00:41:52	16.25
C13	C13ED	Puspalal Buspark-Kirtipur-Balkhu-Kalimati-NAC	3rd (Evening Peak)	D	Pushpalal Buspark-NAC	MiniBus	27	Bagh Bahirab Yatayat	19	30	17	0.63	1.11	16:15:39	16:53:24	11.34	37.75	00:37:45	18.02
C13	C13MC	Puspalal Buspark-Kirtipur-Balkhu-Kalimati-NAC	1st (Morning Peak)	C	NAC-Pushpalal Buspark	MiniBus	27	Bagh Bahirab Yatayat	18	41	40	1.48	1.52	10:24:15	11:04:27	11.77	40.20	00:40:12	17.56
C13	C13DC	Puspalal Buspark-Kirtipur-Balkhu-Kalimati-NAC	2nd (Day Off-Peak)	C	NAC-Pushpalal Buspark	MiniBus	27	Bagh Bahirab Yatayat	18	46	38	1.41	1.70	14:07:13	15:00:44	11.77	53.52	00:53:31	13.19
C13	C13EC	Puspalal Buspark-Kirtipur-Balkhu-Kalimati-NAC	3rd (Evening Peak)	C	NAC-Pushpalal Buspark	MiniBus	27	Bagh Bahirab Yatayat	18	76	60	2.22	2.81	17:09:30	18:16:12	11.77	66.70	01:06:42	10.58
C14	C14MB	Thankot-Kalanki-Kalimati-NAC	1st (Morning Peak)	B	Thankot-Ratnapark	Mini Bus	18	Thankot Nagar Yatayat	22	48	28	1.56	2.67	8:35:13	9:19:13	11.40	44.00	00:44:00	15.55
C14	C14DB	Thankot-Kalanki-Kalimati-NAC	2nd (Day Off-Peak)	B	Thankot-Ratnapark	Mini Bus	18	Thankot Nagar Yatayat	22	37	27	1.50	2.06	12:31:02	13:15:51	11.40	44.82	00:44:49	15.26
C14	C14EB	Thankot-Kalanki-Kalimati-NAC	3rd (Evening Peak)	B	Thankot-Ratnapark	Mini Bus	18	Thankot Nagar Yatayat	22	17	14	0.78	0.94	16:29:13	17:13:11	11.40	43.97	00:43:58	15.56
C14	C14MA	Thankot-Kalanki-Kalimati-NAC	1st (Morning Peak)	A	Rantnapark-Thankot	Mini Bus	18	Thankot Nagar Yatayat	23	38	44	2.44	2.11	9:25:13	10:08:02	13.27	42.82	00:42:49	18.60
C14	C14DA	Thankot-Kalanki-Kalimati-NAC	2nd (Day Off-Peak)	A	Rantnapark-Thankot	Mini Bus	18	Thankot Nagar Yatayat	23	26	17	0.94	1.44	13:25:51	14:19:33	13.19	53.70	00:53:42	14.74
C14	C14EA	Thankot-Kalanki-Kalimati-NAC	3rd (Evening Peak)	A	Rantnapark-Thankot	Mini Bus	18	Thankot Nagar Yatayat	23	40	32	1.78	2.22	17:20:11	18:30:01	13.19	69.83	01:09:50	11.33
C15	C15MD	Lagankhel-Satdobato-Harisiddhi-Godawari	1st (Morning Peak)	D	Godawari-Lagankhel	MiniBus	16	Laganeshwor Mahadev Yatayat	11	37	32	2.00	2.31	9:16:18	9:54:57	10.54	38.65	00:38:39	16.36
C15	C15DD	Lagankhel-Satdobato-Harisiddhi-Godawari	2nd (Day Off-Peak)	D	Godawari-Lagankhel	MiniBus	16	Laganeshwor Mahadev Yatayat	11	11	9	0.56	0.69	14:44:30	15:23:38	10.25	39.13	00:39:08	15.71
C15	C15ED	Lagankhel-Satdobato-Harisiddhi-Godawari	3rd (Evening Peak)	D	Godawari-Lagankhel	MiniBus	16	Laganeshwor Mahadev Yatayat	11	21	18	1.13	1.31	17:27:45	18:03:34	10.20	35.82	00:35:49	17.09
C15	C15MC	Lagankhel-Satdobato-Harisiddhi-Godawari	1st (Morning Peak)	C	Lagankhel-Godawari	MiniBus	16	Laganeshwor Mahadev Yatayat	11	29	20	1.25	1.81	8:37:04	9:12:58	9.48	35.90	00:35:54	15.85
C15	C15DC	Lagankhel-Satdobato-Harisiddhi-Godawari	2nd (Day Off-Peak)	C	Lagankhel-Godawari	MiniBus	16	Laganeshwor Mahadev Yatayat	11	22	21	1.31	1.38	13:53:43	14:23:56	10.23	30.22	00:30:13	20.32
C15	C15EC	Lagankhel-Satdobato-Harisiddhi-Godawari	3rd (Evening Peak)	C	Lagankhel-Godawari	MiniBus	16	Laganeshwor Mahadev Yatayat	11	27	19	1.19	1.69	16:53:51	17:22:35	10.21	28.73	00:28:44	21.33
D16	D16MC	Naya Buspark-Gongabu-Putalisadak-Purano Baneshwor-Sinamangal	1st (Morning Peak)	C	Naya Buspark-Sinamangal	Mini Bus	25	Digo Sarbajanik Yatayat	23	82	57	2.28	3.28	8:49:01	9:52:08	9.83	63.12	01:03:07	9.34
D16	D16DC	Naya Buspark-Gongabu-Putalisadak-Purano Baneshwor-Sinamangal	2nd (Day Off-Peak)	C	Naya Buspark-Sinamangal	Mini Bus	25	Digo Sarbajanik Yatayat	23	56	36	1.44	2.24	12:46:12	13:41:38	9.89	55.43	00:55:26	10.71
D16	D16EC	Naya Buspark-Gongabu-Putalisadak-Purano Baneshwor-Sinamangal	3rd (Evening Peak)	C	Naya Buspark-Sinamangal	Mini Bus	25	Digo Sarbajanik Yatayat	23	49	29	1.16	1.96	15:28:57	16:28:00	9.91	59.05	00:59:03	10.06
D16	D16MD	Naya Buspark-Gongabu-Putalisadak-Purano Baneshwor-Sinamangal	1st (Morning Peak)	D	Sinamangal-Naya Buspark	Mini Bus	25	Digo Sarbajanik Yatayat	21	58	30	1.20	2.32	10:06:03	11:33:06	10.00	87.05	01:27:03	6.89
D16	D16DD	Naya Buspark-Gongabu-Putalisadak-Purano Baneshwor-Sinamangal	2nd (Day Off-Peak)	D	Sinamangal-Naya Buspark	Mini Bus	25	Digo Sarbajanik Yatayat	21	91	49	1.96	3.64	14:02:10	15:11:33	9.71	69.38	01:09:23	8.39
D16	D16ED	Naya Buspark-Gongabu-Putalisadak-Purano Baneshwor-Sinamangal	3rd (Evening Peak)	D	Sinamangal-Naya Buspark	Mini Bus	25	Digo Sarbajanik Yatayat	21	97	62	2.48	3.88	16:42:31	18:05:14	9.77	82.72	01:22:43	7.09
D17	D17MC	Raniban-Dhungedhara-Balaju-Lainchaur-NAC	1st (Morning Peak)	C	Raniban-NAC	Mini Bus	25	Balaju Yatayat	15	68	47	1.88	2.72	8:39:40	9:24:18	7.52	44.63	00:44:38	10.11
D17	D17DC	Raniban-Dhungedhara-Balaju-Lainchaur-NAC	2nd (Day Off-Peak)	C	Raniban-NAC	Mini Bus	25	Balaju Yatayat	15	53	30	1.20	2.12	14:17:12	15:02:54	7.52	45.70	00:45:42	9.88
D17	D17EC	Raniban-Dhungedhara-Balaju-Lainchaur-NAC	3rd (Evening Peak)	C	Raniban-NAC	Mini Bus	25	Balaju Yatayat	15	29	16	0.64	1.16	16:10:32	16:41:07	7.38	30.58	00:30:35	14.48
D17	D17MD	Raniban-Dhungedhara-Balaju-Lainchaur-NAC	1st (Morning Peak)	D	NAC-Raniban	Mini Bus	25	Balaju Yatayat	14	47	36	1.44	1.88	9:26:29	9:59:22	6.34	32.88	00:32:53	11.57
D17	D17DD	Raniban-Dhungedhara-Balaju-Lainchaur-NAC	2nd (Day Off-Peak)	D	NAC-Raniban	Mini Bus	25	Balaju Yatayat	14	73	69	2.76	2.92	15:15:11	16:01:40	6.43	46.48	00:46:29	8.29
D17	D17ED	Raniban-Dhungedhara-Balaju-Lainchaur-NAC	3rd (Evening Peak)	D	NAC-Raniban	Mini Bus	25	Balaju Yatayat	14	71	65	2.60	2.84	16:49:11	17:40:07	6.46	50.93	00:50:56	7.60

OVERALL DATA (ALL 24 PUBLIC TRANSPORTATION ROUTES THREE TRIPS IN BOTH DIRECTION)

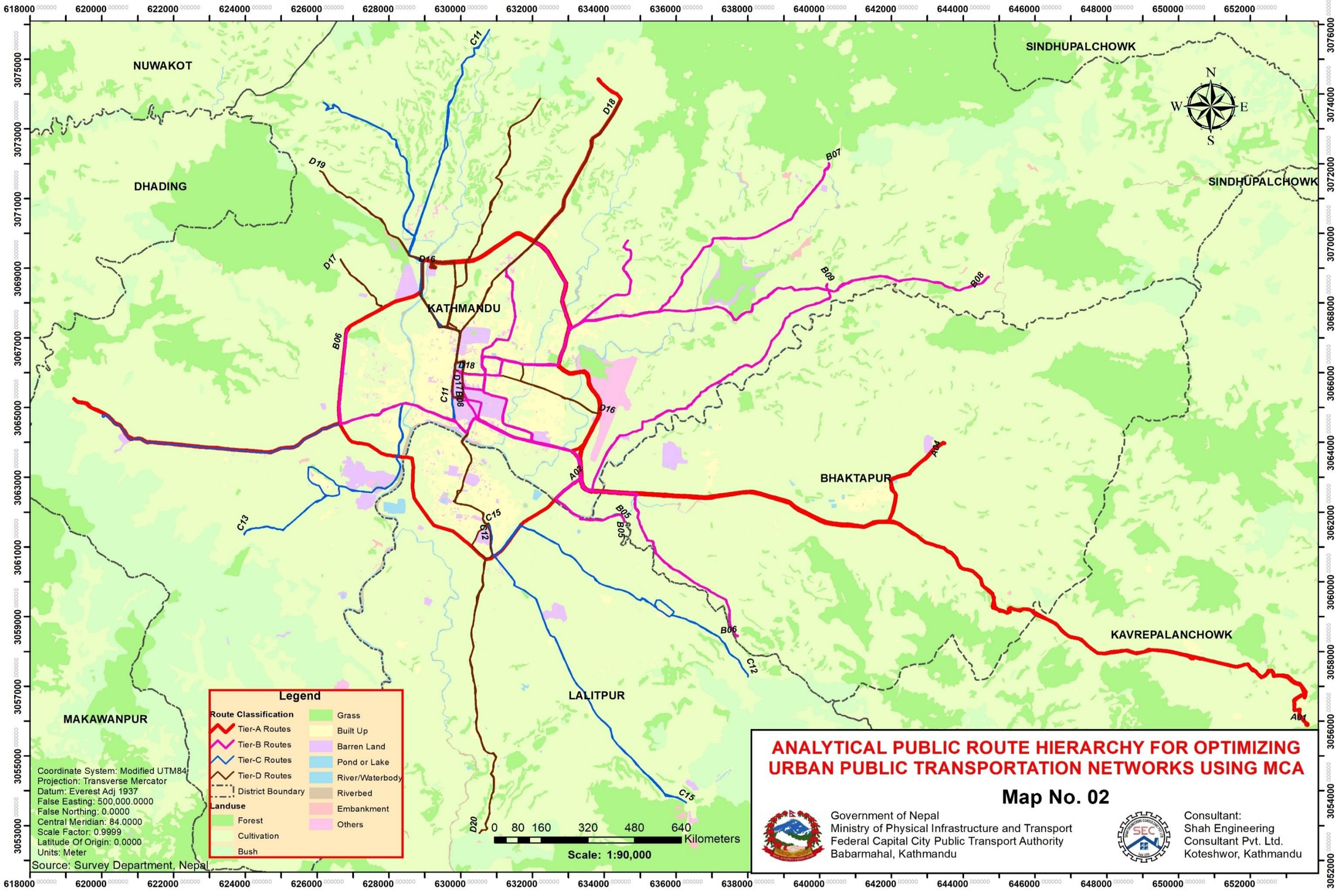
Route No	Route Code	Route Name	RoundTrip	Direction Config	Direction	Vehicle Type	Seat Capacity	Operator	Total Stations	Boarding Total	Max Pax Onboard	Vehicle Load Ratio	Demand Capacity Ratio	Start Time	End Time	Length (km)	Travel Time (in min)	Travel Time (h:m:s)	Average Speed (km/hr)
D18	D18MC	Budhanilkantha-Maharajgunj-Lazimpat-Ratnapark	1st (Morning Peak)	C	Budhanilkantha-Ratnapark	Bus	35	Tarebhir Yatayat	16	59	42	1.20	1.69	8:56:09	9:46:28	9.81	50.32	00:50:19	11.70
D18	D18DC	Budhanilkantha-Maharajgunj-Lazimpat-Ratnapark	2nd (Day Off-Peak)	C	Budhanilkantha-Ratnapark	Bus	35	Tarebhir Yatayat	16	17	15	0.43	0.49	13:11:49	13:50:57	9.71	39.13	00:39:08	14.89
D18	D18EC	Budhanilkantha-Maharajgunj-Lazimpat-Ratnapark	3rd (Evening Peak)	C	Budhanilkantha-Ratnapark	Bus	35	Tarebhir Yatayat	16	45	28	0.80	1.29	15:29:04	16:12:15	9.74	43.18	00:43:11	13.53
D18	D18MD	Budhanilkantha-Maharajgunj-Lazimpat-Ratnapark	1st (Morning Peak)	D	Ratnapark-Budhanilkantha	Bus	35	Tarebhir Yatayat	15	60	37	1.06	1.71	9:49:00	10:33:23	9.32	44.38	00:44:23	12.60
D18	D18DD	Budhanilkantha-Maharajgunj-Lazimpat-Ratnapark	2nd (Day Off-Peak)	D	Ratnapark-Budhanilkantha	Bus	35	Tarebhir Yatayat	15	22	19	0.54	0.63	13:52:00	14:40:28	9.30	48.47	00:48:28	11.52
D18	D18ED	Budhanilkantha-Maharajgunj-Lazimpat-Ratnapark	3rd (Evening Peak)	D	Ratnapark-Budhanilkantha	Bus	35	Tarebhir Yatayat	15	59	42	1.20	1.69	16:14:00	17:07:31	9.45	53.52	00:53:31	10.59
D19	D19MC	Goldhunga-Machhapokhari-Balaju-Lainchaur-NAC	1st (Morning Peak)	C	Goldhunga-NAC	MiniBus	27	Tarkeshwor Yatayat	18	66	58	2.15	2.44	7:58:10	8:37:11	9.30	39.02	00:39:01	14.31
D19	D19DC	Goldhunga-Machhapokhari-Balaju-Lainchaur-NAC	2nd (Day Off-Peak)	C	Goldhunga-NAC	MiniBus	27	Tarkeshwor Yatayat	18	29	17	0.63	1.07	13:30:17	14:11:31	8.58	41.23	00:41:14	12.49
D19	D19EC	Goldhunga-Machhapokhari-Balaju-Lainchaur-NAC	3rd (Evening Peak)	C	Goldhunga-NAC	MiniBus	27	Tarkeshwor Yatayat	18	30	20	0.74	1.11	16:15:06	16:54:32	9.38	39.43	00:39:26	14.27
D19	D19MD	Goldhunga-Machhapokhari-Balaju-Lainchaur-NAC	1st (Morning Peak)	D	NAC-Goldhunga	MiniBus	27	Tarkeshwor Yatayat	18	29	26	0.96	1.07	8:40:13	9:28:05	8.48	47.87	00:47:52	10.63
D19	D19DD	Goldhunga-Machhapokhari-Balaju-Lainchaur-NAC	2nd (Day Off-Peak)	D	NAC-Goldhunga	MiniBus	27	Tarkeshwor Yatayat	18	36	24	0.89	1.33	14:12:31	14:52:36	8.25	40.08	00:40:05	12.35
D19	D19ED	Goldhunga-Machhapokhari-Balaju-Lainchaur-NAC	3rd (Evening Peak)	D	NAC-Goldhunga	MiniBus	27	Tarkeshwor Yatayat	18	60	35	1.30	2.22	16:55:32	17:53:40	8.26	58.13	00:58:08	8.52
D20	D20MD	Lagankhel-Satdobato-Thecho-Chapagaun-Takhel Chautara	1st (Morning Peak)	D	Takhel Chautara-Lagankhel	MiniBus	29	Laganeshwor Mahadev Yatayat	14	65	54	1.86	2.24	9:12:20	10:09:44	9.97	57.40	00:57:24	10.42
D20	D20DD	Lagankhel-Satdobato-Thecho-Chapagaun-Takhel Chautara	2nd (Day Off-Peak)	D	Takhel Chautara-Lagankhel	MiniBus	29	Laganeshwor Mahadev Yatayat	14	36	30	1.03	1.24	14:25:55	15:16:24	10.09	50.48	00:50:29	11.99
D20	D20ED	Lagankhel-Satdobato-Thecho-Chapagaun-Takhel Chautara	3rd (Evening Peak)	D	Takhel Chautara-Lagankhel	MiniBus	29	Laganeshwor Mahadev Yatayat	14	7	6	0.21	0.24	18:32:39	19:09:07	9.98	36.47	00:36:28	16.42
D20	D20MC	Lagankhel-Satdobato-Thecho-Chapagaun-Takhel Chautara	1st (Morning Peak)	C	Lagankhel-Takhel Chautara	MiniBus	29	Laganeshwor Mahadev Yatayat	14	15	14	0.48	0.52	8:26:32	9:04:52	9.90	38.33	00:38:20	15.49
D20	D20DC	Lagankhel-Satdobato-Thecho-Chapagaun-Takhel Chautara	2nd (Day Off-Peak)	C	Lagankhel-Takhel Chautara	MiniBus	29	Laganeshwor Mahadev Yatayat	14	36	30	1.03	1.24	13:32:15	14:18:56	9.74	46.68	00:46:41	12.52
D20	D20EC	Lagankhel-Satdobato-Thecho-Chapagaun-Takhel Chautara	3rd (Evening Peak)	C	Lagankhel-Takhel Chautara	MiniBus	29	Laganeshwor Mahadev Yatayat	14	64	56	1.93	2.21	17:09:28	18:04:53	9.71	55.42	00:55:25	10.51
D21	D21MC	Chandeshwori-Tokha-Samakhusi-Lainchaur-NAC	1st (Morning Peak)	C	Chandeshwori-NAC	Micro	18	Samakushi Yatayat	11	36	23	1.28	2.00	8:29:08	9:06:58	10.61	37.83	00:37:50	16.82
D21	D21DC	Chandeshwori-Tokha-Samakhusi-Lainchaur-NAC	2nd (Day Off-Peak)	C	Chandeshwori-NAC	Micro	18	Samakushi Yatayat	11	31	17	0.94	1.72	13:18:40	14:01:19	10.79	42.65	00:42:39	15.18
D21	D21EC	Chandeshwori-Tokha-Samakhusi-Lainchaur-NAC	3rd (Evening Peak)	C	Chandeshwori-NAC	Micro	18	Samakushi Yatayat	11	8	6	0.33	0.44	16:26:30	17:06:52	10.78	40.37	00:40:22	16.03
D21	D21MD	Chandeshwori-Tokha-Samakhusi-Lainchaur-NAC	1st (Morning Peak)	D	NAC-Chandeshwori	Micro	18	Samakushi Yatayat	11	34	30	1.67	1.89	9:09:58	9:48:16	9.91	38.30	00:38:18	15.52
D21	D21DD	Chandeshwori-Tokha-Samakhusi-Lainchaur-NAC	2nd (Day Off-Peak)	D	NAC-Chandeshwori	Micro	18	Samakushi Yatayat	11	25	22	1.22	1.39	14:04:19	14:50:44	9.85	46.42	00:46:25	12.73
D21	D21ED	Chandeshwori-Tokha-Samakhusi-Lainchaur-NAC	3rd (Evening Peak)	D	NAC-Chandeshwori	Micro	18	Samakushi Yatayat	11	37	29	1.61	2.06	17:10:52	18:04:04	10.22	53.20	00:53:12	11.53
D22	D22MD	Lagankhel-Jawalakhel-Maitighar-Ratnapark	1st (Morning Peak)	D	Lagankhel-Ratanpark	Micro	20	Laganeshwor Mahadev Yatayat	12	20	20	1.00	1.00	8:48:33	9:21:21	5.91	32.80	00:32:48	10.81
D22	D22DD	Lagankhel-Jawalakhel-Maitighar-Ratnapark	2nd (Day Off-Peak)	D	Lagankhel-Ratanpark	Micro	20	Laganeshwor Mahadev Yatayat	12	18	16	0.80	0.90	12:50:51	13:16:45	5.88	25.90	00:25:54	13.62
D22	D22ED	Lagankhel-Jawalakhel-Maitighar-Ratnapark	3rd (Evening Peak)	D	Lagankhel-Ratanpark	Micro	20	Laganeshwor Mahadev Yatayat	12	19	19	0.95	0.95	17:09:56	17:42:09	5.91	32.22	00:32:13	11.01
D22	D22MC	Lagankhel-Jawalakhel-Maitighar-Ratnapark	1st (Morning Peak)	C	Ratanpark-Lagankhel	Micro	20	Laganeshwor Mahadev Yatayat	10	31	25	1.25	1.55	9:35:02	10:06:23	5.77	31.35	00:31:21	11.05
D22	D22DC	Lagankhel-Jawalakhel-Maitighar-Ratnapark	2nd (Day Off-Peak)	C	Ratanpark-Lagankhel	Micro	20	Laganeshwor Mahadev Yatayat	10	26	19	0.95	1.30	13:33:15	14:06:10	5.69	32.92	00:32:55	10.37
D22	D22EC	Lagankhel-Jawalakhel-Maitighar-Ratnapark	3rd (Evening Peak)	C	Ratanpark-Lagankhel	Micro	20	Laganeshwor Mahadev Yatayat	10	32	22	1.10	1.60	17:57:14	18:29:41	5.71	32.45	00:32:27	10.55

ANNEX-II: GIS MAPS

ANALYTICAL PUBLIC TRANSPORTATION ROUTE HIERARCHY: SELECTED ROUTES



ANALYTICAL PUBLIC TRANSPORTATION ROUTE HIERARCHY: TIER-WISE ROUTES



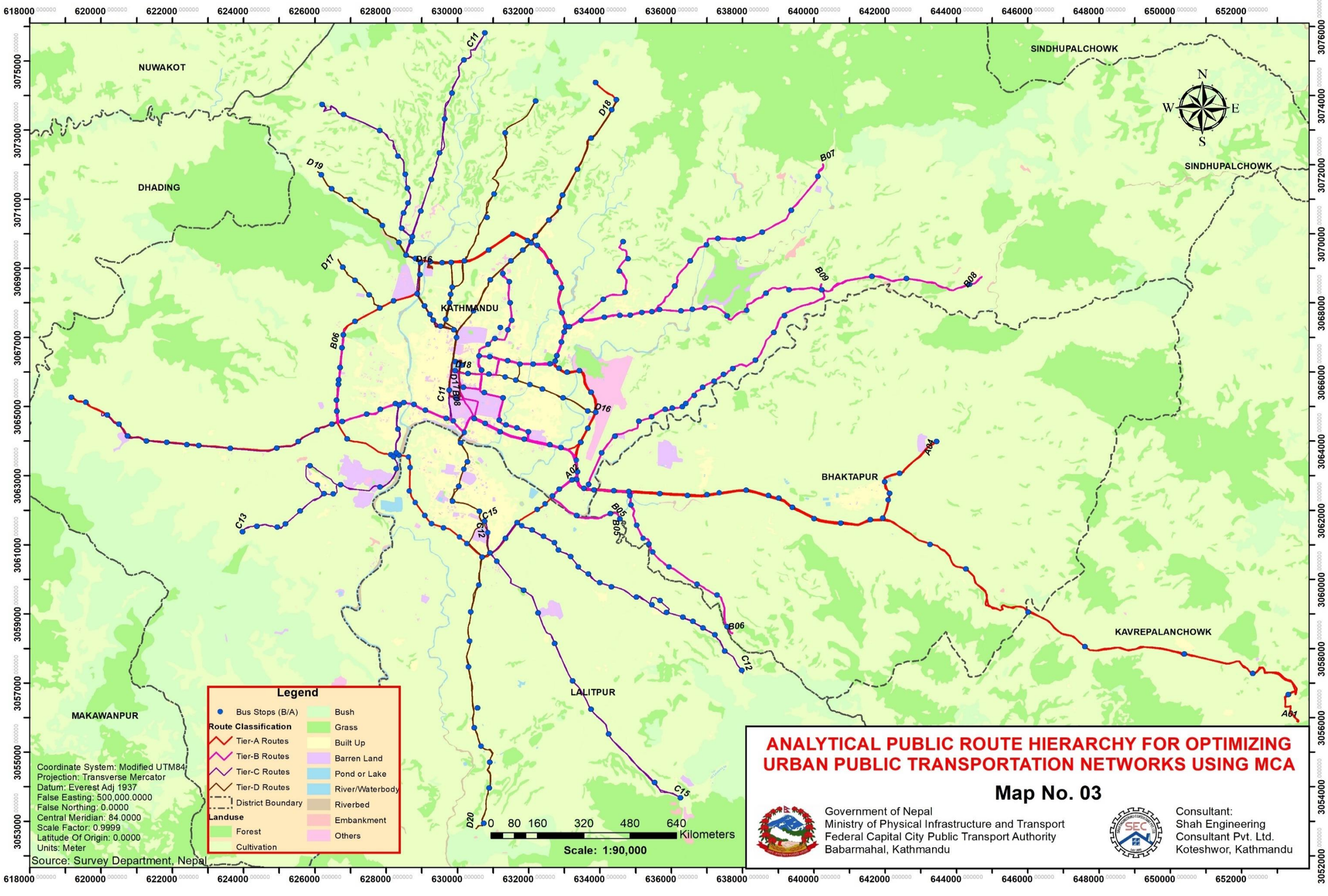
ANALYTICAL PUBLIC ROUTE HIERARCHY FOR OPTIMIZING URBAN PUBLIC TRANSPORTATION NETWORKS USING MCA

Map No. 02

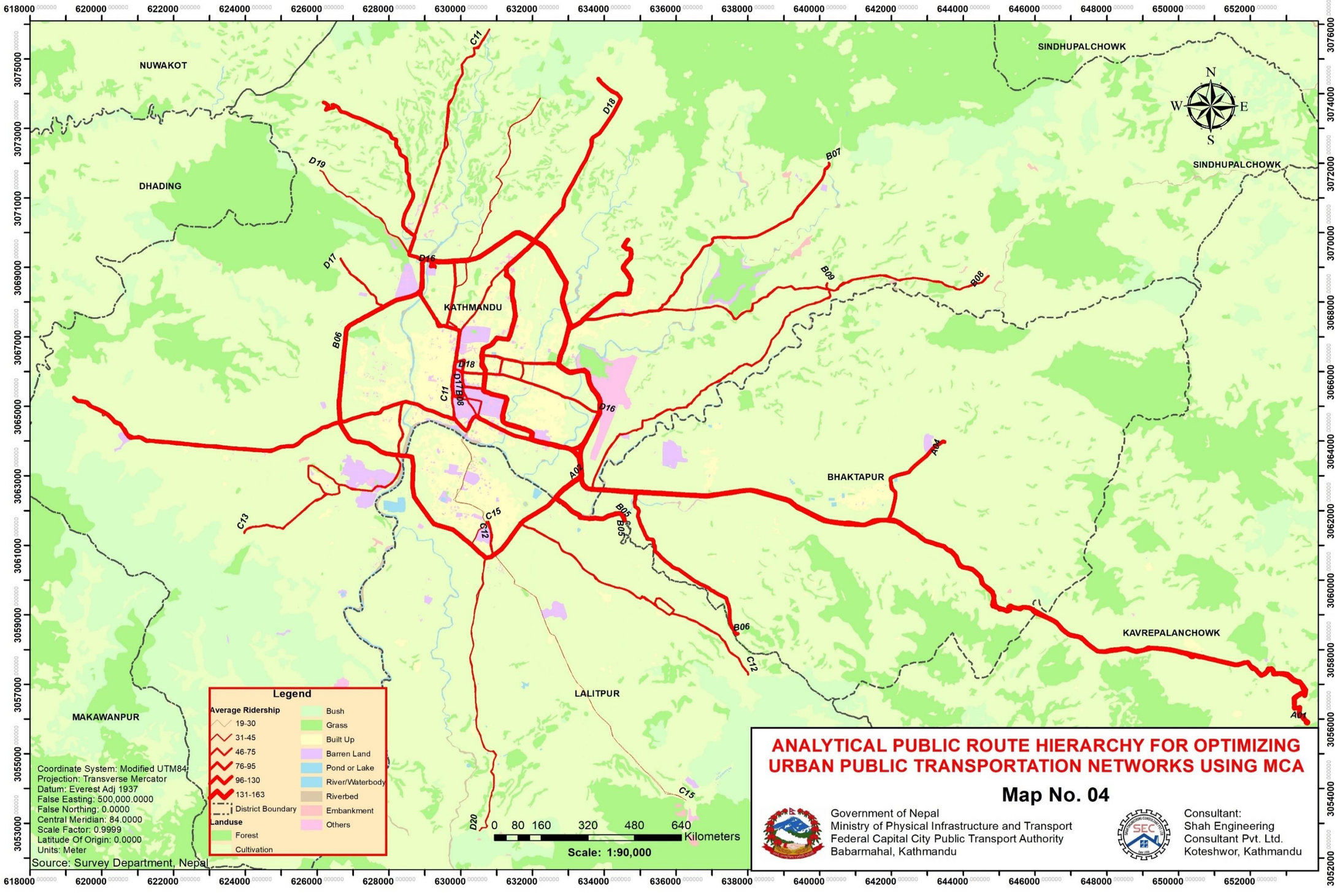
Government of Nepal
Ministry of Physical Infrastructure and Transport
Federal Capital City Public Transport Authority
Babarmahal, Kathmandu

Consultant:
Shah Engineering
Consultant Pvt. Ltd.
Koteshwor, Kathmandu

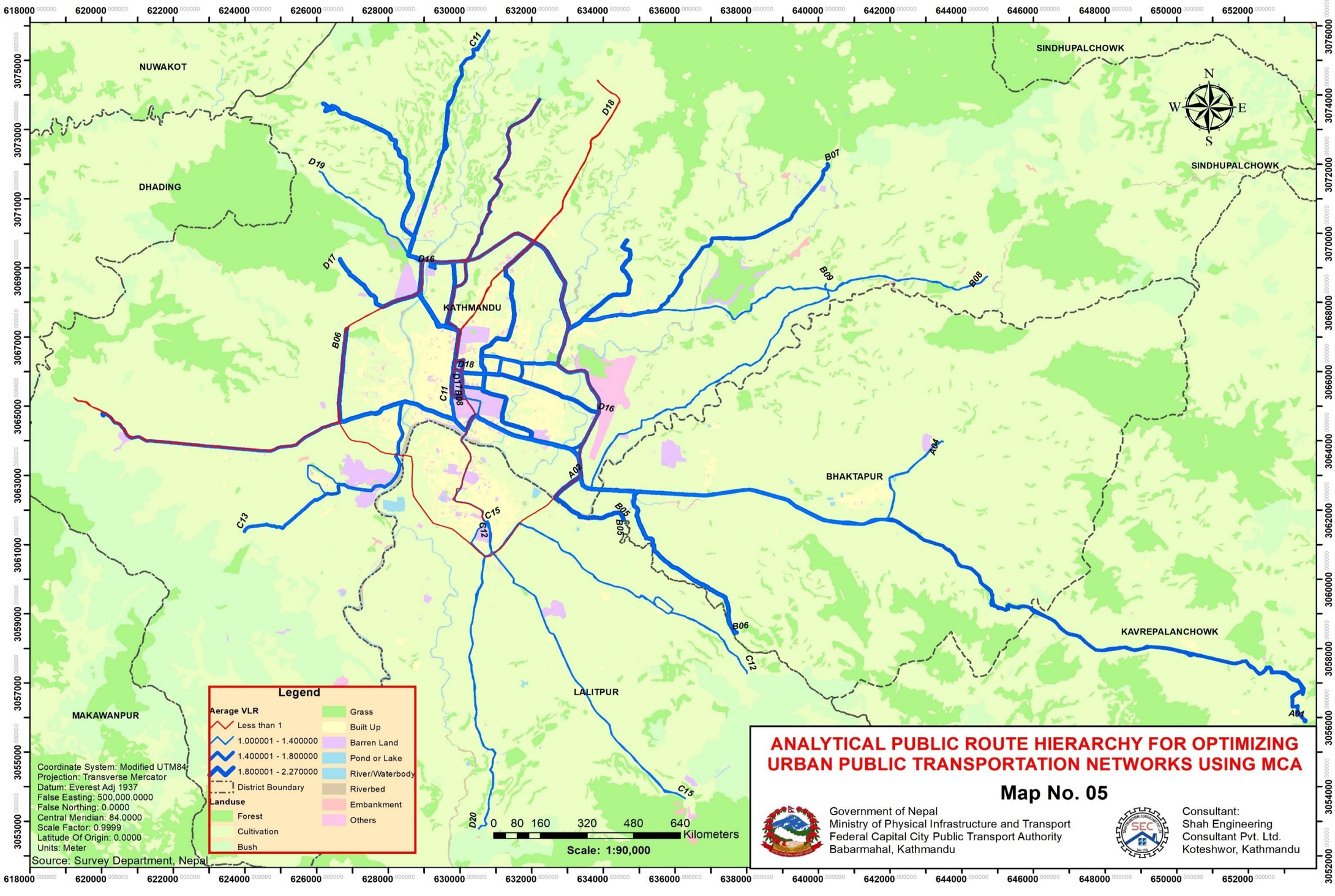
ANALYTICAL PUBLIC TRANSPORTATION ROUTE HIERARCHY: ROUTES & BOARDING ALIGHTING STOPS



ANALYTICAL PUBLIC TRANSPORTATION ROUTE HIERARCHY: LINE WEIGHT MAP FOR AVERAGE RIDERSHIP



ANALYTICAL PUBLIC TRANSPORTATION ROUTE HIERARCHY: LINE WEIGHT MAP FOR VEHICLE LOAD RATIO



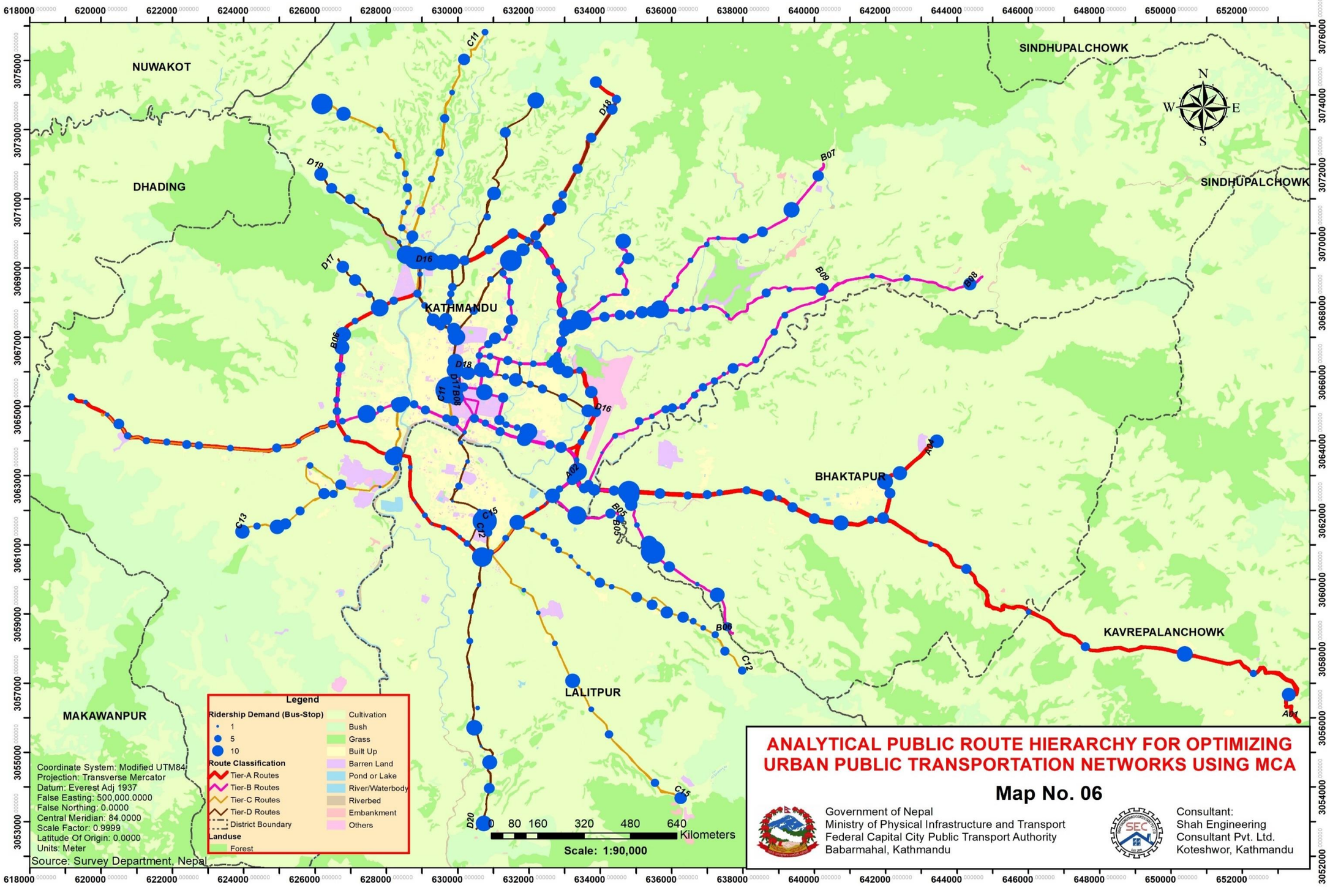
ANALYTICAL PUBLIC ROUTE HIERARCHY FOR OPTIMIZING URBAN PUBLIC TRANSPORTATION NETWORKS USING MCA

Map No. 05

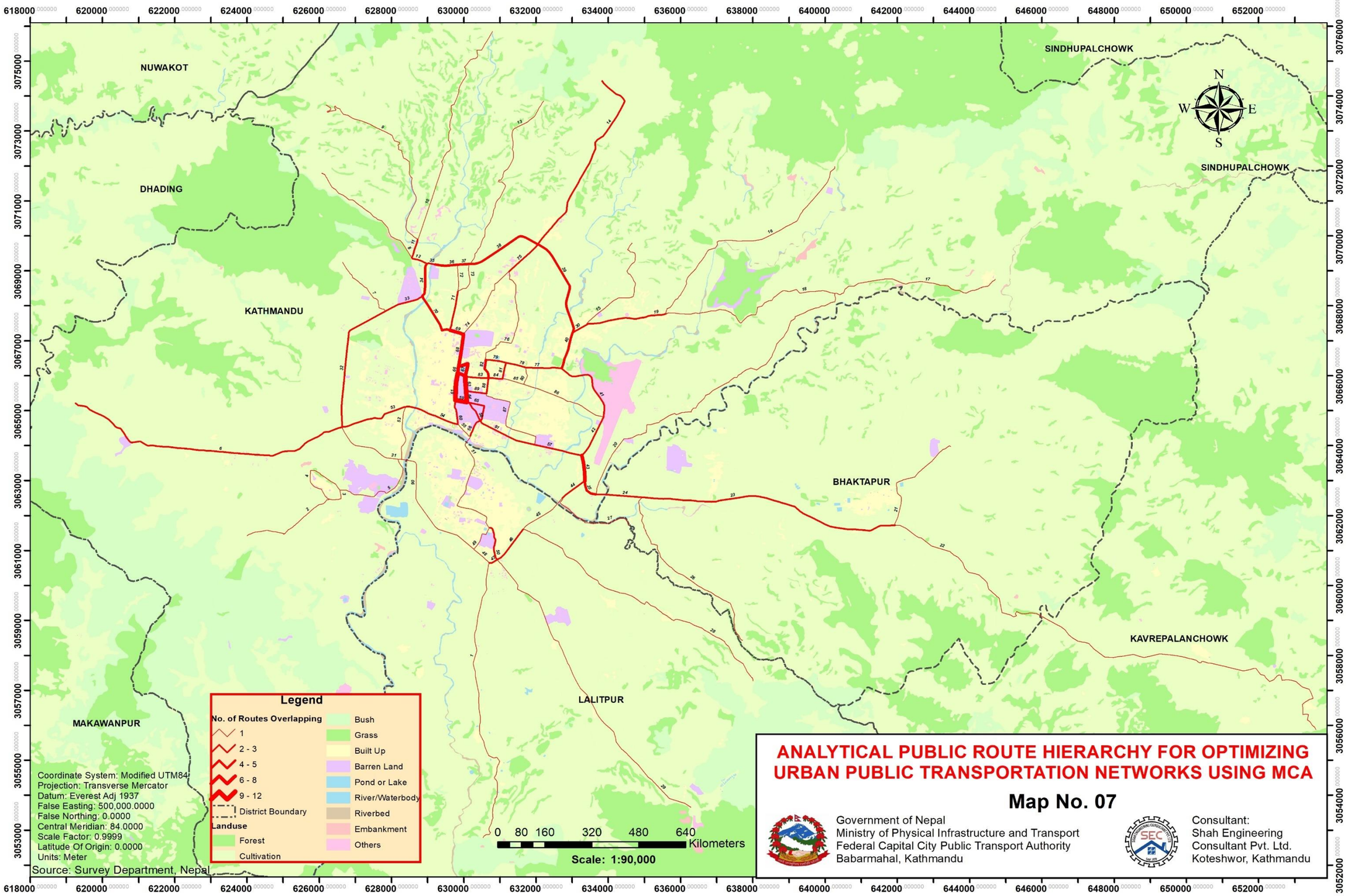
Government of Nepal
Ministry of Physical Infrastructure and Transport
Federal Capital City Public Transport Authority
Babarmahal, Kathmandu

Consultant:
Shah Engineering
Consultant Pvt. Ltd.
Koteshwor, Kathmandu

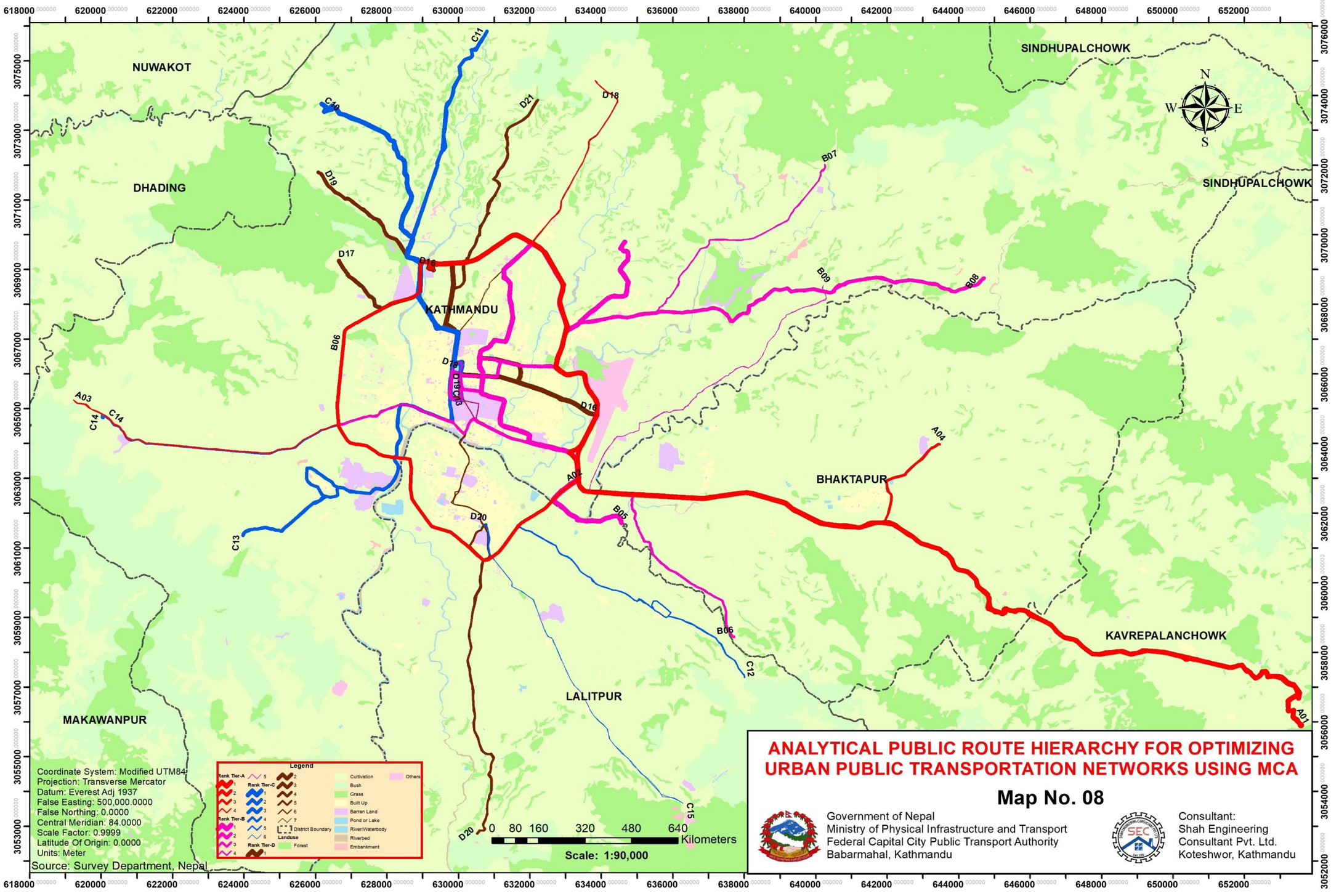
ANALYTICAL PUBLIC TRANSPORTATION ROUTE HIERARCHY: RIDERSHIP DEMAND HEATMAP AT BUS-STOPS



ANALYTICAL PUBLIC TRANSPORTATION ROUTE HIERARCHY: CRITICAL SECTIONS ALONG THE SELECTED ROUTES



ANALYTICAL PUBLIC TRANSPORTATION ROUTE HIERARCHY: TIER-WISE RANKING OF ROUTES



ANALYTICAL PUBLIC ROUTE HIERARCHY FOR OPTIMIZING URBAN PUBLIC TRANSPORTATION NETWORKS USING MCA

Map No. 08

Government of Nepal
Ministry of Physical Infrastructure and Transport
Federal Capital City Public Transport Authority
Babarmahal, Kathmandu

Consultant:
Shah Engineering
Consultant Pvt. Ltd.
Koteshwor, Kathmandu